AN ECONOMIC ANALYSIS OF LAKE REHABILITATION/STABILIZATION PROJECTS: MIRROR/SHADOW LAKES AND WHITE CLAY LAKE

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ERS Staff Report

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ABSTRACT

Ex ante analysis techniques are developed and applied to estimate the economic impacts of two lake water quality projects. The application of property value impacts and recreation demand models to one project produced an estimated flow of benefits nearly twice the costs. In the other project, because of low recreation use, the estimated benefits were barely half the costs.

Key Words: Economic analysis, economic impacts, water quality improvement, property values, recreation demand.

CONTENTS

PREFACE

This economic study was part of a comprehensive evaluation financed in part by an EPA research grant to the University of Wisconsin. The Economic Research Service of the U.S. Department of Agriculture collaborated on the economic portions of the evaluation which are reported here. The larger evaluation also looked at social impacts and management structure, and made recommendations. A complete final report which discusses all aspects of the evaluation is: SOCIO-ECONOMIC IMPACT EVALUATION OF LAKE IMPROVEMENT PROJECTS AND LAKE MANAGEMENT GUIDELINES, by Nicolaas W. Bouwes, Sr. and Lowell Klessig, Center for Resource Policy Studies, University of Wisconsin, Working Paper No. 17, October 1982.

SUMMARY

Ex ante analysis techniques are developed to analyze the economic impacts associated with water quality improvement projects. These techniques include a property value impact model, a recreation demand model, and a linear program farm impact model. These models were applied to a lake rehabilitation project undertaken at an urban park (Mirror and Shadow Lakes) and to a lake stabilization project at White Clay Lake in an agricultural watershed.

The use of the *ex ante* models employed in this study will allow projects to be examined prior to implementation thereby providing a mechanism for choosing between competing projects as well as assuring economic efficiency.

In the analysis of the Mirror and Shadow Lakes rehabilitation project application of the property value impact and recreation demand models indicate that the flow of benefits is approximately twice the cost of project implementation. The property value impact model also revealed that the impact of benefits was not commensurate with the costs incurred. This resulted from the inverse relationship between benefits received and distance from the water resource. Consequently, if it is desired that taxes be levied on a "benefits received" criteria then property owners should be taxed accordingly. The property value impact model offers the mechanism whereby this can be accomplished.

The analysis of the White Clay Lake stabilization project indicated that benefits were barely half the project costs. This is attributable to the low recreation use rate. With an annual increase in the use rate of 3 percent, annual benefits would equal costs.

Although recreation benefits were not substantial at White Clay Lake, the LP model revealed that the adoption of manure storage facilities by farmers would produce substantial savings to nutrient retention and reallocation of labor and capital resources. This result suggests that there exists direct economic incentives for dairy farmers to participate in such a program at subsidy rates lower than current rates without negatively impacting their financial position. Such reductions in government cost-share rates would free resources for additional water quality improvement efforts.

The White Clay Lake analysis revealed conditions unlike those at Mirror and Shadow Lakes in Waupaca where a high use rate of the lake insured that benefits would exceed costs, thereby making project selection an easy choice. However, in the White Clay Lake situation the assumption of a modest 3 percent in usage revealed that benefits would equal costs. Such a sensitivity analysis suggests that projects should not necessarily be dismissed when costs exceed benefits without first considering issues such as discount rate, growth rates, option values, existence values, irreversibilities, etc. If reasonable assumptions regarding these factors produce favorable results, then decision-makers may want to further consider projects that initially appear unjustified.

INTRODUCTION

The passage of the 1972 Amendments to the Federal Water Pollution Control Act (P. L. 92-500) reflected society's disenchantment with the deterioration of the Nation's water resources. P. L. 92-500 set a national goal of fishable and swimmable water by 1983, authorized major funding, and established a series of subprograms. Pursuant to Section 314 of this act, one of these subprograms became known as the Clean Lakes Program.

In 1976, the Environmental Protection Agency (EPA) awarded the first grants to communities to restore and rehabilitate their lakes. Mirror and Shadow Lakes in the city of Waupaca, Wisconsin, and White Clay Lake in Shawano County, Wisconsin were among the first awardees.

In the city of Waupaca, Mirror and Shadow Lakes were showing the impact of nutrients discharged from storm sewers, while at White Clay Lake, excess nutrient flow came primarily from farmland and barnyards in the agricultural watershed. Implementation funds for the relevant lake rehabilitation (Mirror/Shadow Lakes) and stabilization (White Clay Lake) projects was provided by EPA, the State, and local sources. To deal with the nutrient-rich storm water in Waupaca, a storm-sewer diversion project coupled with lake aeration and alum treatment was undertaken. In the White Clay Lake watershed, the stabilization project consisted of manure storage facilities, upgrading barnyards, diversions, and other watershed improvements.

Due to the pervasiveness of the water quality problem the familiar problem of allocating scarce resources among competing uses became readily apparent. Consequently, EPA wanted to know if the benefits

generated by a project justified the costs, and how they might rank those applicants competing for the limited resources available for water quality improvement projects.

EPA addressed this objective by allocating 10 percent of Section 314 dollars for the evaluation of several initial projects. Evaluations were to be designed to ascertain impacts on the lake ecosystem and the surrounding human community. The two Wisconsin projects were to be the subject of such an evaluation. The EPA evaluation grant was provided to meet the following economic objectives:

1. Ascertain and evaluate the economic impacts of the Mirror/Shadow Lake rehabilitation and White Clay Lake stabilization projects; and
2. Contribute to the development of a project selection procedure based upon an _ex ante_ evaluation of water quality improvement projects.

To address these objectives in the present analysis the economic models used to assess the project impacts will be presented. This will be followed by a description of the communities, the water resource, the projects and an application of the relevant economic models. The report will conclude with a discussion of the policy implications based upon the economic analysis.

ECONOMIC ANALYSIS: MODEL SPECIFICATION

Once a project and its objectives have been clearly defined, the next major steps in performing an economic analysis are to properly identify and quantify the associated impacts. In both of the project settings it is hypothesized that the primary benefits generated will be recreational in nature. This is consistent with other studies that have estimated that recreational impacts will comprise anywhere from 50 to 95 percent of the project benefits (1, 43). 1/ In the case of Mirror and Shadow Lakes in Waupaca, it is plausible to expect additional benefits in the form of aesthetics. And at White Clay Lake it was realized that the adoption of the manure storage facilities may impact the farm enterprise as well. The models to be employed to estimate these impacts must account for a change in water quality as well as provide for an *ex ante* analysis. These models are described below.

To estimate impacts at Waupaca, both a property value model and recreation demand model were used. Both utilize a water quality explanatory variable. A property value impact model is employed based on the hypothesis that all local benefits will be capitalized in property values.

The estimation of recreation benefits allows a check on the estimate generated by the property value model. Since most water quality impacts are assumed to reside in recreational benefits, one would expect, once having made allowance for nonlocal recreators, that the recreational benefits estimate will approximate, but be smaller than property value impacts. Therefore, the recreation model provides

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1/Underscored numbers in parentheses refer to literature listed in the references.

an estimate of the recreational component of benefits, as well as other impacts by calculating the difference between the estimates of the two methods. And, finally, it provides an estimate of the benefits accruing to nonlocal recreators that are not included in the estimate of property value impacts.

The same recreational model that was used for the Waupaca analysis was used for the White Clay Lake analysis. However, since the project area is strictly agricultural it was deemed more appropriate that a linear program (LP) model be used to simulate farm activity to determine the project impact, rather than employing a property value impact model as in Waupaca.

Property Value Impact Model

The model to be described in this section was developed in an earlier study which yielded a generic method to assess the property value impact from any water resource improvement project (8). This model is based on the assumption that water quality improvements are capitalized in property values, and the benefits vary inversely with the distance from impacted property to the water's edge. Then, by isolating the property value changes which result from increases in water quality from other pertinent variables, and by expressing these changes as a function of distance from the water, the variation in benefits accruing to households at different locations with respect to the improved water resource can be analyzed. Performing this analysis at different sites allows for the determination of the effects of different degrees of water quality.

Once having determined that the variation in water quality produces different impacts, it was necessary to devise a water quality variable that would account for this effect. Furthermore, it had to be a variable that would reflect perceived changes, as changes that are unrecognized will not provide benefits. By relating the observed variation in property value to the perceived water quality and the various water body characteristics, the model was then capable of predicting property value changes as a function of water quality changes, thereby satisfying the criteria specified above. The model will be summarized below; however, the interested reader is referred to Dornbusch for a more detailed presentation (8).

The basic premise of this theoretical section is that water resource projects have value to the general public which, in the absence of a market in which this output is directly sold, are adequately reflected in the market prices of those properties situated near the resource.

Often a public project serves to enhance the productivity or utility of a specific location. Whenever this occurs, benefits accrue to firms and households in that location. This effect of increasing the value of certain locations results in the initial equilibrium in the land market being disturbed. Eventually new equilibrium land values are established. The total benefits from such programs equal the sum of the changes in productivity and utility over all firms and households; this is represented by the sum of the changes in land values from the initial equilibrium to the new equilibrium (21).

Classical rent theory asserts that the changes in utility or productivity can be measured by changes in land rents. The rationale is that the rental value of a piece of land is bid up until it eliminates

the surplus or profit. Benefits can be measured then by the changes in these rents. However, in order that changes in land prices accurately reflect benefits it is necessary that all surpluses resulting from water quality change be eliminated by the land market and that there be no induced changes in the prices of other goods and households. Freeman states that, where land is used for residential and private recreational purposes rather than for production for the market, the "no price change" assumption seems reasonable and the zero surplus assumption may be reasonable under conditions analogous to the open city model as would be the case of a small lake which is part of a much larger urban housing market (10) These conditions are closely approximated in Waupaca thereby allowing the application of the property value model If these assumptions are unreasonable it is possible to assume that there is no change in consumer surplus. This is accomplished by indexing the property market by distance to the water, then by creating a situation where the supply of property is constant and perfectly inelastic and hence no available surpluses with demand shifts (8).

The benefits from a water resource depend on both the quantity and quality of the resource available to the consumer. The quantity of benefits or services from a water resource is a function of one's accessibility to that water resource. It is reasonable to assume then that more benefits accrue to residents living closer to the resource than do those living further away. Consequently, the benefits from a change in water quality, and hence its effect on property values will diminish with greater distance from the water resource.

Also, the magnitude of property value changes depends in part on the amount of land which is considered to be impacted by the project. Industrial land benefits are excluded since industrial production costs are relatively insensitive to water quality, and property value benefits for these lands are expected to be too insignificant to warrant their inclusion (8, pp.75-97). Since we are dealing with only day trippers and primarily local recreators it is assumed in this case, that commercial impacts would be minimal. Consequently, the impact of water quality improvements in a public park are considered only with respect to residential property values in this model.

The qualitative aspect of the causality that has been postulated between a change in water quality and property values can be demonstrated in Figure 1. Consider the initial demand for housing, D(WQ), given the

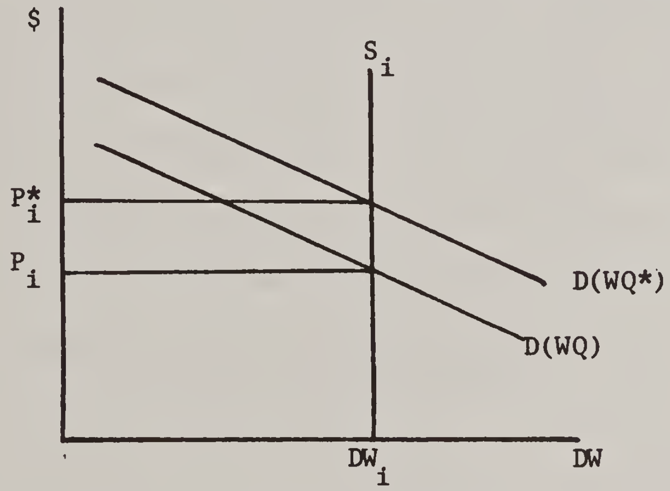


Figure 1--Demand for Housing

fixed supply, S_i at distance DW_i. The equilibrium price under these conditions is P_i. Now, consider an increase in water quality which shifts the demand curve to D(WQ*). The new equilibrium price is now increased to P_i^*. This change in price reflects the change in willingness to pay for a change in water quality.

Thus, the basic model postulates first that a perceived change in water quality by area residents will be represented by a change in property values and secondly that the impact on property values decreases as distance from the resource increases. As pointed out by Dornbusch, economic theory provides few clues as to the functional forms appropriate of economic relationships, and the presence of random error terms in stochostically specified equations adds an element of ambiguity; therefore it is necessary to deduce the appropriate form from earlier studies of both theoretical and empirical nature (8). However, Freeman has shown that these earlier studies provide only one point on the consumer's marginal value curve, and therefore, do not provide sufficient information to identify the demand curve for water quality (10). To deal with this problem a two-step procedure utilizing pooled data from a number of study sites was employed (8). The first step estimates property price change functions across submarkets indexed by distance to the water's edge. In the second stage, all the site analyses are pooled. With the assumption consumers behave alike across sites the sites specific estimates can be interpreted as point estimates of the same marginal utility curve and can be combined to identify the marginal utility function which can be used to estimate the benefits from future water quality changes.

In the first step of the estimating procedure the site-specific model is represented by the general function:

$$\Delta P_{ij} = f_i(DW_{ij}, PWQI_{ij}, A_{ij}, u_{ij}) \qquad (1)$$

where ΔP_{ij} is the observed price change for property i at site j, DW_{ij}

is the quantity of water resources that is approximated by a function of the property's distance to the water's edge, $PWQI_{ij}$ is the Perceived Water Quality Index whose role is that of WQ presented in Figure 1 and represents the quality of water resources, A_{ij} is all other site amenities, and u_{ij} is the random error term.

Given that it is the change in prices from one period to the next that is of interest as well as the change in the PWQI and A variables the statistical model can be specified as follows: 2/

$$\Delta P\% = \beta_{oj} + \beta_{1j}(1/DW_j) + \sum_{i=2}^{n} \beta_{ij} A_{ij} + u_{ij} \qquad (2)$$

where $\Delta P\%$ equals the percentage change in property value at the different sites and 1/DW reflects the hypothesized inverse relationship between change in property value and distance to the resource. This model is estimated at each of the various sites. See Appendix B of Dornbusch for details of each study site (8).

The second step requires the estimation of b_{1j} in the generic model

$$\Delta P\%_j = b_{oj} + b_{1j}\ (1/DW_j). \qquad (3)$$

This is accomplished by regressing the observed variation in the estimate b_{1j} across sites against perceived water quality and water body characteristics such as public access (PA), water body type (WBT), and water body size (WBS) at the various sites, i.e.,

$$b_{1j} = f(PWQI_j, PA_j, WBT_j, WBS_j, v_{ij}). \qquad (4)$$

2/Freeman, in his text published after this analysis was conducted, takes issue with this specification (10). However, this ad hoc model provides results that appear reasonable when compared to the recreation benefit estimates as will be demonstrated below.

A two stage least-squares procedure was used to estimabe B_1 due to the simultaenity problem created by the variable $PWQI_{Res}$ which becomes endogenous, and the same exogenous variable, water body type, that appears in both equations. Result of this procedure is:

$$\ln b_i = 6.398 + .492\ (\ln PWQI_{Res}) + 1.180\ (\text{WBT Lake}) + .991\ (\text{WBT Bay}) \quad (5)$$

(t-statistic) (3.438) (3.416) (2.562)

$R^2 = .948$

d.f. = 13

It is assumed in the generic model represented in equation (3) that $E\ (b_{1j}) = \beta_{1j}$; and that the individual site estimates represent points on a marginal value function which is common to all consumers, thus permitting the evaluation of water quality change.

The final, estimated, property value impact model to be employed in the forecasting of the economic benefits of a water quality improvement for Mirror and Shadow Lakes is:

$$\Delta P\%_d = b_o + b_1\ (1/DW_d) \quad (3)$$

$$b_1 = e^{6.398} (PWQI_{Res})^{0.492} e^{1.180\ (\text{WBT Lake})} \quad (5)$$

$$b_o = b_1\ (1/DW_{max}) \quad (6)$$

$$PWQI_{Res} = -24.778 + 0.463\ (PWQI_{Exp}) + 15.50\ (\text{Public Access}) \quad (8)$$

Equation (6) completes the model as $\Delta P\%$ must be equal to zero at the outer edge of the impact area. Since $b_1(1/DW)$ is never zero then an

offsetting term is needed to bring the property value to zero for the limiting value of DW--equation (6) performs this role. The subscript d is added to equation (3) as the evaluation will be conducted by distance determined zones. The derivation of equation (8), the Perceived Water Quality Index, is presented next.

Perceived Water Quality Index

The quantitative aspect of the causal chain that has been postulated between a change in water quality and property values is more complicated than Figure 1 suggests. A change in the water quality of a given water resource must be perceived by residents of the area, and it is this perception of water quality changes which then affects the value of their properties. If an actual water quality change remains unnoticed, or if what is noticed is not valued, no benefits will result. Perceived change may have little or no correspondence to factual changes. Likewise, what is technically important in water quality may bear little if any, resemblance to what the lay public considers valuable. An index must be used to describe which water quality aspects are perceived by people and to what extent, and these perceptions must be weighted according to residents' valuation of the different water quality characteristics comprising the change. The PWQI was developed by Dornbusch and Associates to provide a statistically significant explanatory variable in the economic model designed to estimate the impact of water quality changes on property values (8). In this effort a survey was conducted at representative sites throughout the U.S. to determine what the public considered to be indicators of water quality. The primary water quality aspects

understood by lay people were found to be (1) industrial waste, (2) debris in or on the water, (3) clearness of the water, (4) algae in the water, (5) odor from the water, (6) wildlife support capacity of the water body, and (7) the recreational opportunities offered by the water body.

The relative importance of these seven aspects of water quality were determined by having the respondents weight them. The capacity to support wildlife and the recreational opportunity provided by the water resource were viewed as the most important aspects while the presence of algae was deemed the least offensive. The weights reported were .10, .05, .07, .04, .05, .43 and .26, respectively.

After identifying and weighting the relevant subjective water quality parameters, the respondents were then provided with five descriptions of water quality conditions for each of the seven water quality parameters. An example is presented here for recreation opportunity:

A. The water quality is good enough to permit swimming fishing and boating, as well as picnicking, walking relaxing or sunbathing along the water's banks.

B. The water quality is good enough to permit all of the activities mentioned above, except that you <u>cannot swim</u> in the water.

C. The water quality is good enough to permit all of the activities mentioned above, except that you <u>cannot</u> either <u>fish or swim</u> in it.

D. The water quality is only good enough to permit walking, picnicking, relaxing or sunbathing along the water's bank; you <u>cannot boat, fish, or swim</u> in it.

E. The poor water quality will permit <u>no recreation</u> activities in or near the water.

Next, respondents were requested to rate the degree of acceptability of each of these conditions on a scale of zero for totally unacceptable to twelve for totally acceptable. A standardized grid was developed to

transform the vertical axis to "percent of attainable benefits". A curve was then fitted to the mean acceptability of each category for the parameter in question. An example is shown in Figure 2 for recreation opportunities. Here, as with the other measures of water quality, the curve exhibits an "S" shape which indicates that a certain threshold in water quality has to be reached before an improvement will yield benefits and that there exists a point beyond which further improvement yields diminishing returns in terms of residents' evaluation of change. Not only is this intuitively appealing, but such a phenomena has been substantiated in psychophysical experimentation, and is consistent with economic theory (8).

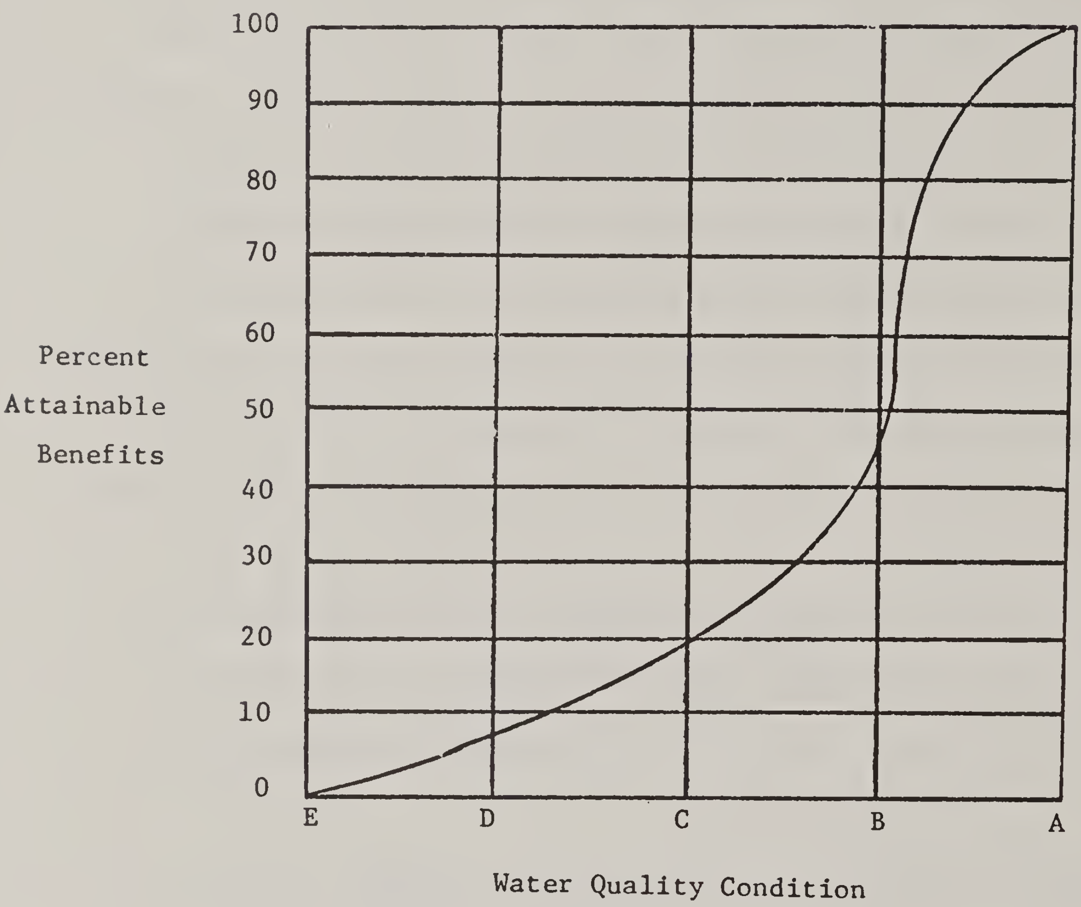
For later use in the economic evaluation percent attainable benefit tables, based upon the "S" curves, were constructed for each of the water quality parameters. An example of such a matrix is presented in Table 1 for recreational opportunity.

These tables are used in the following manner: After a change in water quality has been achieved for a given resource, the consensus of the community with regards to the amount of change for each of the seven categories would be ascertained through a survey. The amount of change would take the form of "from condition _____ to condition _____." The corresponding value would be extracted from the table and multiplied by the relative weighting for that category. This would be done for all seven categories, and the resulting values summed to give a value representing the Perceived Water Quality Index by residents. Mathematically this is presented by:

$$PWQI_{Res} = \sum_{k=1}^{7} a_k B_{ijk} \qquad (7)$$

Figure 2--Percent Attainable Benefits for Recreation Opportunity

(Relative Weighting $a_7 = .26$)



Water Quality Condition	Description
A	The water quality is good enough to permit swimming, fishing and boating, as well as picnicking, walking, relaxing or sunbathing along the water's banks.
B	The water quality is good enough to permit all of the activities mentioned above, except that you <u>cannot swim</u> in the water.
C	The water quality is good enough to permit all of the activities mentioned above, except that you <u>cannot</u> either <u>fish or swim</u> in it.
D	The water quality is only good enough to permit walking, picnicking, relaxing or sunbathing along the water's banks; you <u>cannot boat, fish, or swim</u> in it.
E	The poor water quality will permit <u>no recreation</u> activities in or near the water.

Table 1--Percent Attainable Benefit Matrix
(B_{ijk}) for Recreation Opportunity

Relative Weighting $a_7 = 0.26$

From i \ To j	E	D	C	B	A
E	0	7	20	45	100
D	-7	0	13	38	93
C	-20	-13	0	25	80
B	-45	-38	-25	0	55
A	-100	-93	-80	-55	0

Water Quality Condition	Description
A	The water quality is good enough to permit swimming, fishing and boating, as well as picnicking, walking, relaxing or sunbathing along the water's banks.
B	The water quality is good enough to permit all of the activities mentioned above, except that you <u>cannot swim</u> in the water.
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E	The poor water quality will permit <u>no recreation</u> activities in or near the water.

where $PWQI_{Res}$ is the perceived water quality index of residents, a_k is the relative weighting of category k, and B_{ijk} is the value of attainable benefits reflecting the change from condition i to condition j for the k^{th} category.

For the purpose of project justification, however, such an ex post procedure is of little value. To allow for an ex ante project valuation it is necessary to predict the lay person's perception of water quality and water quality change. While water quality experts cannot tell a planner what the changes perceived by residents will be they can translate the technical water quality changes sought and expected through the project into the kinds of change deemed relevant to residents.

The task then is to predict the residents $PWQI_{Res}$ with the expert's ex ante $PWQI_{Exp}$. This relationship was estimated by Dornbusch using pooled, cross-section data from 17 sites across the U.S. based upon experts' responses to the same questions presented the lay person. The estimated relationship was found to be:

$$PWQI_{Res} = -24.778 + .463\ (PWQI_{Exp}) + 15.50\ (PA) \qquad (8)$$

$$\text{(t-statistic)}\ (-3.107)\quad (3.546)\qquad\qquad (5.266)$$

$$R^2 = .741$$
$$\text{d.f.} = 13$$

where Public Access takes a value of 1, 2, or 3 depending upon the degree of public accessibility to the lake as based upon shoreline accessibility.

Recreation Benefit Model

Although it is argued here that the property value model presented above ostensibly captures all local project benefits, most researchers realize that the benefits estimated are incomplete to the extent that benefits accruing to the users who come from outside the project area are not reflected in property values.[3/] Consequently, it is necessary to employ an approach that will complement the property value model and estimate these benefits.[4/]

This issue will be addressed by employing the method proposed by Bouwes et al., viz., by: (1) presenting a theoretical foundation from which an empirical analysis will build; (2) establishing a framework by which water quality can be accounted for in the model; (3) presenting a model which includes the essential water quality variable; and (4) synthesizing these components by advancing a method which can be applied *ex ante* to decision making situations (2).

The Theoretical Model

Consistent with the framework by Mäler, an individual's utility is represented as a function of consumption activities, A, and environmental services, E:

$$U = U\ (A,\ E), \tag{9}$$

where the utility function, U, is assumed to be quasi-concave, continuous and increasing in A and E, and consumer preference functions are assumed

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3/McMillan also argues that property values might underestimate benefits as increased taxes due to higher property values will be capitalized into the price of the property.

4/On-site interviews at Shadow Lake in Waupaca revealed that approximately fifteen percent of the recreators were nonlocals.

to be convex (23). By assuming the existence of weak complementarity, e.g., those situations where the consumption of a private good, such as swimming in lake (A_1), is a necessary prerequisite of the enjoyment of a given environmental quality, such as water quality of that lake (E_1), then it is possible to derive the benefits (costs of a quality change in a public good (environmental service) from information on the demand for the private good. This condition of weak complementarity is expressed in mathematical terms by:

$$\frac{\partial\ U(0,A_2,\ldots,\ A_m,\ E_1,\ldots,E_n)}{\partial\ E_1} = 0 \qquad (10)$$

where consumption $A = A_1, \ldots,\ A_m$ and the accompanying environmental service $E = E_1, \ldots, E_n$.

Also embodied in this notion of weak complimentarity is the assumption that there are no option values, or that if the demand for some private good is zero, then so is the marginal willingness to pay for some environmental quality. An example is the case of water-related recreation, the use of which is influenced by the level of water quality. Those who would not use the lake are then assumed to be indifferent to changes in water quality.

It can now be shown that if condition (10) exists, and if there is no option value it is possible to compute the demand price for the environmental service. Consider the income compensated demand curve D, for recreation trips when quality of water is WQ as depicted in Figure 3. At the price P the recreator demands T trips, and the consumer surplus is the triangle ABC. If the level of water quality increases to WQ^*, it is assumed to

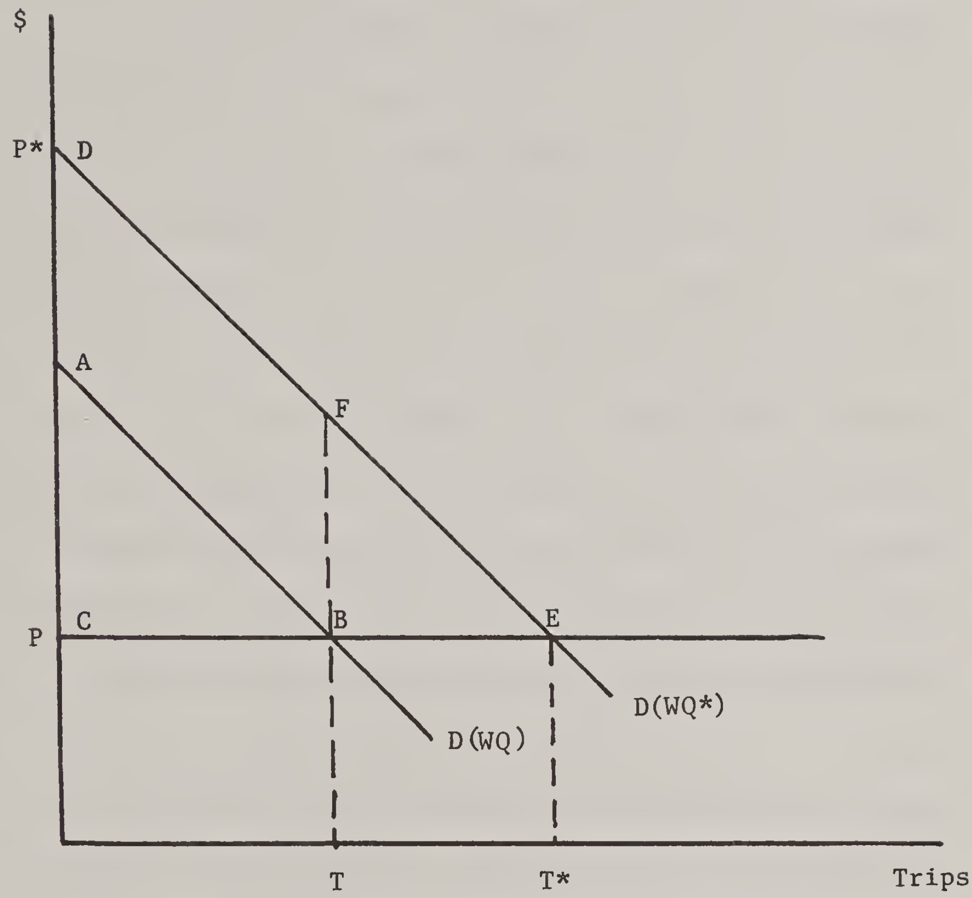

Figure 3--Benefits Under Complementing Conditions

increase the marginal utility per trip and shift the demand curve to position D^*; the recreator now demands T* trips. The new consumer surplus is the area DEC, and the net change in consumer surplus is given by the area BADE. 5/ The question to be answered is how much is the consumer willing to pay for this change in water quality?

Calculation of the benefits associated with a change in water quality as represented by willingness to pay can proceed in three stages: (a) A change in price from P to P^*: given the demand curve D, the individual must be compensated by the corresponding consumer surplus ABC so as not to be made worse off by the price change; (b) A change in water quality from WQ to WQ^*: given the assumption of weak complementarity, the consumer's utility is unaffected and thus there is no need for compensation; (c) A change in price back to P: the consumer is willing to pay the new consumer surplus as represented by the area DEC. The net result is the difference between the sonsumer surplus before and after the water quality change. In other words, the consumer would be willing to pay BADE for some improvement in water quality. The first step in making such a determination is the estimation of the demand curve for recreation, as measured by trips (T), that is a function of water quality.

5/To use consumer surplus as a measure of resource value it is necessary to make two basic assumptions. First, that all other prices other than the good in question are held constant. And second, that the benefits do not change the real income of the beneficiaries. In other words, the area under the demand curve reflects the Marshallian measure of consumer surplus. However, research by Willig has demonstrated that the above assumptions are not that restrictive that they should invalidate the resulting estimates of consumer surplus. He states that in those instances where the consumer's income elasticity is in the range of ± 1.0, and "if the surplus area under the demand curve between the old and new prices is 5 percent of income (or less), then the conpensating variation is within 2 percent of the measured consumer's surplus." Certainly both of these assumptions are realistic for the case at hand. (40)

The Travel Cost Model

Most recreational demand curve estimation procedures are based upon the travel-cost approach proposed by Hotelling (15). This method hypothesizes that recreational demand estimations can be made by examining the correlation between the recreator's frequency of visits and costs (money, time, etc.) incurred. The resulting estimated demand schedules can then be used to predict how recreators will react to price changes of the recreation site thus allowing for the estimation of the site demand curve and consumer surplus.

This approach has been refined over the years by Trice and Wood (45), Clawson (5), Kneese (19) and others. More recent statistical sophistications have been made through the use of individual observations rather than grouped data allowing better model specifications and more accurate resource evaluations (3), (13). All of these methods have been applied to evaluating the total recreational resource, but not in assessing the impact of a resource attribute such as water quality.

Some of the more recent efforts to estimate the effect of a change in water quality on the value of recreation resources have concentrated on the estimation of those benefits that would be attributable to the change in one or more physical parameters that contribute to the quality of water, e.g., recreation benefits increase as the dissolved oxygen concentration level rises (19), (6). Stevens hypothesized that the quality of the recreation experience (fishing) is a function of angling success which is a function of water quality (41). Reiling et al. employed use-intensity factors of water related activities that were supplied by Forest Service and Environmental Protection Agency personnel (35). The major

shortcoming of these efforts is that the techniques do not contain a systematic relationship between the subjective index used as a proxy for water quality and the physically measurable water quality parameters, and perhaps more importantly, with recreators' perception of water quality.

Objective and Subjective Water Quality Relationship

Ultimately, the eixstence or nonexistence of benefits from a water quality change are determined by whether the water user recognizes an improvement. If an actual water quality change remains unnoticed, or if what is noticed is not valued by the recreationists, no benefits will result. In order to estimate ex ante the benefits that will accrue to recreationists as a result of a water quality improvement, it is necessary to predict how lake users perceive water quality.

Since water resource experts use objective and sophisticated criteria such as dissolved oxygen content, biochemical oxygen demand in parts per million and turbidity standards, it is necessary to determine the relationship between this objective rating of water quality and the typical recreator's subjective rating.

To ascertain if such a relationship exists it is necessary to seek an objective water quality index. The choice is Uttormark's Lake Condition Index (LCI), which was developed in 1975 to classify all Wisconsin lakes larger than 100 acres (48). The lake classification index is based on penalty points accumulated for four parameters: dissolved oxygen in hypolimnion (0-6 penalty points) secchi disk transparence (0-4 penalty points); fish winterkill (0-4 penalty points); and algae growth (0-9 penalty points). The penalty points range from 0-23. A lake with poor water quality would accumulate a large number of penalty points and would consequently have a high LCI value.

The relationship between the LCI and subjective water quality ratings had been previously examined by obtaining information from on-site interviews at eight southeastern Wisconsin lakes (37). Recreators were asked to rate lake water quality on a 0-23 scale such as that used by the LCI. The effectiveness of the LCI in predicting the public's perception of water quality was tested by regressing the average subjective rating ($\bar{R}$) of all recreators for each lake on the corresponding LCI for that lake. The results of this were encouraging, yielding the equation:

$$\ln \bar{R} = 1.948 + \underset{(3.37)}{.364}\text{LCI} \qquad R^2 = .69 \qquad (11)$$

With this equation and a limnologist's estimates of the changes in LCI that would take place with and without the project, the recreationist's subjective perception of this change could be predicted.

Encouraged by the results of this previous study, questions regarding user's water quality perceptions were included as part of a random statewide telephone survey of Wisconsin households. Each respondent was asked to rate the water quality of the lake in question on the same 0-23 scale. This survey provided a cross-section sample of 723 observations among 243 Wisconsin lakes. Attempts to duplicate the pretest results, though proved unsuccessful as indicated by initial regressions's insignificant estimators and low coefficients of determination, suggesting that the LCI was not very effective in "explaining" the public's perception of water quality.

These results may be attributable, however, to the different methods used in gathering information. In the previous research, responses were

obtained by on-site interviews, whereas, the statewide sample was gathered through a telephone survey of a representative sample. This survey was conducted in October and November of 1978 and questioned respondents about their recreational activities between Labor Day 1977 and Labor Day 1978. Therefore, it is possible that the telephone survey technique introduces a recall factor bias where the respondent, being distant in space and time from the lake, cannot give as accurate a rating as he/she could have if they had been interviewed at the site. Another explanation may be that the telephone interview, as opposed to an on-site interview, is inappropriate for a rating on a 23 point scale.

As indicated above, the most desirable procedure for estimating the benefits of water quality change is having a recreation demand model which includes a user's subjective water quality variable, and a link between this variable and a measurable, objective water quality variable, as used by the natural scientists, that will allow prodication of change in the subjective variable. The next most desirable arrangement, that will still allow for an *ex ante* analysis, would be to use the objective water quality variable directly in the demand equation.

This latter approach requires a few observations on a large cross-section of many lakes of differing degrees of water quality, thereby allowing for a determination of the correlation between differing numbers of trips and water quality. In the current analysis this condition is satisfied by the statewide sample which included 243 lakes with typically one, two or three observations at each. In the earlier study the data were gathered at only eight lakes with many observations of each (2). Under these circumstances it was imperative that the individual's subjective water quality ratings rather than the LCI be used to determine the correlation between visits and water quality.

The Statistical Model

The general form of the model used to estimate water quality benefits is that employed by Bouwes and Schneider:

$$T_{ij} = \alpha + \sum_{k=1}^{n} \beta_k X_{ijk} + e_{ij}, \qquad (\underline{12})$$

where T_{ij} is the number of trips by decision-making unit i to lake j, X_{ijk} is the error term ($\underline{2}$). The primary objective is to estimate a statistical demand curve with reliable estimates of the structural variables --particularly those of the cost variable from which the resource value is derived, and the water quality variable which is used to determine the economic significance of a change in water quality.

The initial general model included a set of regressions deemed to be consistent with economic theory and findings from previous recreation demand studies. Daytrips were hypothesized to be a function of the already mentioned round-trip travel costs and water quality variable as well as other variables deemed pertinent. Travel time is considered to be a cost of recreation and was included. Family income was included to account for the income effect on the decision maker. Tastes and preferences for related activities were represented by number of trips to all lakes visited. The number of other lakes visited was used to reflect substitutes; this choice is based on the assumption that it is only the lakes that the recreator is aware of that constitute the relevant substitutes in his choice set. Recognizing that other site amenities distinguish sites, other variables reflecting water quality, lake size, availability of facilities, etc., were included.

Various functional forms were attempted in the estimation of the demand relationship --linear, linear in reciprocal, quadratic, semi-log, inverse semi-log, double log and translog. Each was run with the variables specified in the general model. When each of the functional forms of the general models was run, a plot of residuals against predicted values suggested that heteroscedasticity might be present. This was adjusted for in the manner proposed by Glejser (12). Once the data was properly weighted to deal with the heteroscedasticity the models were run again and variables were eliminated via F-tests to determine if their inclusion produced a significant difference.

Regressions based upon the entire statewide sample did not produce a significant demand equation. Since Northern Wisconsin lakes possess a considerably higher level of water quality, as determined by the Lake Classification Index, it was suspected that northern lake recreators might constitute a different population than southern lake users. Consequently, the state sample was divided into Northern and Southern counties and the regression analysis repeated. This effort provided statistically significant results that are reported below. Also, this sub-sample choice had intuitive appeal as the Shadow Lake is a northern lake used exclusively by daytrippers.

As indicated the data is based on individual observations. One of the justifications for utilizing data based on individual observations is that it reduces the multicollinearity between the cost and time variables that are present when zone averages are used, thereby allowing the inclusion of both in the estimation of the demand curve. When zoned averages are

used, time is typically omitted. This produces a cost coefficient having too great a magnitude and hence an underevaluation of the resource. However, for the case at hand the use of individual observations did not alleviate the problem of multicollinearity. Consequently, it was necessary to compensate for this problem. This problem can be addressed by either omitting one of the variables, which then produces a biased estimator for the remaining variable, or by constructing a composite variable which would account for the presence of both variables. This latter alternative is consistent with economic theory that prescribes determining a value for travel time and adding this to actual travel costs. In other words, costs are presented as:

$$C^{\lambda}_{ij} = C_{ij} + \delta_i t_{ij} \qquad (13)$$

where C^{λ}_{ij} is equal to total trip costs for individual i to lake j, C_{ij} is equal to round-trip travel costs, δ_i is the opportunity cost of time for decisionmaking unit i, and t_{ij} is round-trip travel time to lake j.

In order to utilize this form of the cost variable it is necessary to determine the appropriate value for δ_i, that is, what is the relevant opportunity cost of time. Cesario suggests that the value of time with respect to nonwork travel is between one-fourth and one-half of the wage rate (4). The former value was selected in an effort to maintain conservative benefit estimates. 6/ The opportunity value of time was determined from the reported income figures which were reduced to an hourly rate and applied to the round-trip travel time. 7/ The final estimated demand curve for visits is:

6/The use of lower cost figures, other variable values remaining the same, yields more elastic demand curve estimates and consequently smaller accompanying resource values.

7/The wage rate for housewives and students was set equal to the state minimum wage of $2.55 per hour (August 1977).

$$T_o = \underset{(2.84)}{16.1651} - \underset{(2.18)}{3.1533} \ln C^\lambda - \underset{(1.77)}{5.4242} \ln LCI + \underset{(1.83)}{.3312} Y \quad n = 52 \quad (14)$$

where T_o is the number of visits for the year, C^λ is the travel cost per trip plus the opportunity cost of travel time, LCI is the lake classification index, and Y is the recreator's income.

Economic Benefits Under Current and Alternative Water Quality Conditions

To estimate the flow of benefits attributable to the project it is necessary to estimate those benefits that would accrue each year with the project and the loss of benefits that would occur without the project -- the sum of these represents the relevant benefits. To accomplish this a two-step evaluation process is employed. This approach requires applying the derived statistical demand curve to each individual observation obtained at the site to be evaluated, and using the observed cost and visit data to reflect behavior at zero additional site cost. This is then used to estimate an aggregate demand curve for the total recreation experience from which the resource value is estimated. For example, by introducing a change in the costs term, c, into equation (14) the estimate of visits becomes:

$$T_c = 16.1651 - 3.1533 \ln (C^\lambda + c) - 5.4242 \ln LCI + .3312 Y \quad (15)$$

Substituting equation (14) into equation (15) and simplifying yields:

$$T_c = T_o + 3.1533 (\ln C^\lambda - \ln(C^\lambda + c)). \quad (16)$$

Consumer surplus can be expressed as:

$$CS_i = \int_o^{c_{max}} [T_o + 3.1533 (\ln C^\lambda - \ln(C^\lambda + c))] dc \quad (17)$$

where CS_i is consumer surplus for decision making unit i and c_{max} is the level of added cost which results in no trips demanded. Since the travel cost model is based upon the presumption that travel and time costs in getting to and from the resource trace out a demand curve for that resource, then the maximum cost that recreators can be expected to pay is dependent upon the behavior of that individual living the farthest away from the resource and incurring the highest travel costs. The maximum, c_{max}, then was set equal to that cost level where the individual with the highest initial travel costs would no longer utilize the resource.

To determine total benefits this result is then expanded by the representation rate of that observation. The representation rate, or weighting factor, (Ψ) is determined by the response rate: the total number of recreators at the site to be evaluated divided by the product of the average number of trips and party size of the sample and the number of observations in the sample. These expanded individual demand curves then are summed horizontally to construct the aggregate demand curve from which the resource value, (RV), is estimated, e.g., the area under this aggregate curve is represented by equation (18) and reflects the consumer surplus associated with the resource: 8/

$$RV = \sum_{i-1}^{n} \Psi \ CS_i \tag{18}$$

To estimate the annual benefits associated with a change in water quality, i.e., BADE in Figure 3, it is necessary to determine how a change

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8/It is necessary to assume that the demand functions are aggregates of homogeneous groups of recreators, i.e., similar tastes and preferences, react the same to price changes, etc. (16). However, this assumption is mitigated by the use of individual observations (11, p.564).

in water quality will modify recreation behavior. To determine the effect of a water quality change, the demand equation can be rewritten as:

$$T_o^* = T_o - 5.4242 \; (\ln \; (LCI + \ell) - \ln LCI) \qquad (19)$$

where T_o^* is the estimated number of trips demanded by decision-making unit i given a change in water quality as reflected by ℓ. Substituting T_o^* for T_o into equation (16) yields the desired results. Consumer surplus associated with a change in water quality, CS_i^*, can now be estimated by:

$$CS_i^* = \int_o^{c_o} [T_o^* + 3.1533 \; (\ln C^\lambda - \ln \; (C^\lambda + c))] \; dc \qquad (20)$$

Total resource value with the change in water quality is determined by:

$$RV^* = \sum_{i=1}^{n} \Psi \; CS_i \qquad (21)$$

The resulting change in resource value under various levels of water quality can be determined by calculating the difference between the initial resource value, as determined by equation (18), and that occurring after the water quality change, as calculated by equation (21), i.e.,

$$\Delta RV = |RV^* - RV| \qquad (22)$$

The absolute value is required as a decline in WQ will create a situation where RV = RV^*, a negative value. However, these are to be interpreted as benefits as these are costs avoided by the project.

To perform <u>ex ante</u> analysis of an expected water quality change it is necessary to (a) establish the resource value with current water quality conditions; and (b) determine the impact associated with a change in water quality both with and without the project.

This can be achieved given the procedures described above and a limnologist's estimated schedule of water quality changes both with and without the project.

LP Farm Impact Model

Since phosphorous was considered to be the limiting factor in the White Clay Lake eutrophication process, it was determined that the lake stabilization project efforts should be directed to controlling this nutrient at its source. Given the pervasiveness of the dairy farms in the watershed it was felt that the resolution of this problem would be best handled by the instatllation of manure storage facilities and modification of crop management practices to be consistent with such facilities.

The impacts of adopting this form of nonpoint source pollution control technique extends beyond the single accounting cost of this facility. The farm enterprise will find it necessary to reallocate its capital and human resources, and it will possibly experience reduced fertilizer costs due to increased nutrient retention, and perhaps a change in crop output. Consequently, it is necessary to do more than merely examine the capital costs of the manure storage facility to determine total farm impact -- it is necessary to observe the farm operation with the facility in operation. This of course is not possible within the time frame of this study. Therefore, some means had to be devised to simulate the farm enterprise operation in order to estimate the farm impacts.

To accomplish this, a linear program (LP) model of a dairy farm operation was used to simulate the impact on profitability that would result from the adoption of manure storage facility. The model was further expanded to examine how a revenue-maximizing farmer might adjust to varying subsidy rates, cost-sharing rules, and erosion control legislation.

A linear programming optimization procedure is used to identify the combination of activities which maximize annual farm income (or annual pretax earnings) subject to the resource constraints of the farm. The objective function is defined to be the sum of annual farm receipts, e.g., from milk, cull cattle, etc., less the sum of annual out-of-pocket costs. In this model, we assume that all activities conducted on a dairy farm are characterized by constant returns to scale, and all non-land resources are freely mobile within the farm.

Details of the farm resource limits, and the set of farming activities were made on the basis of interviews with a northern Wisconsin farmer. This primary information source was supplemented by agricultural research publications and by assumptions on the design of public policy.

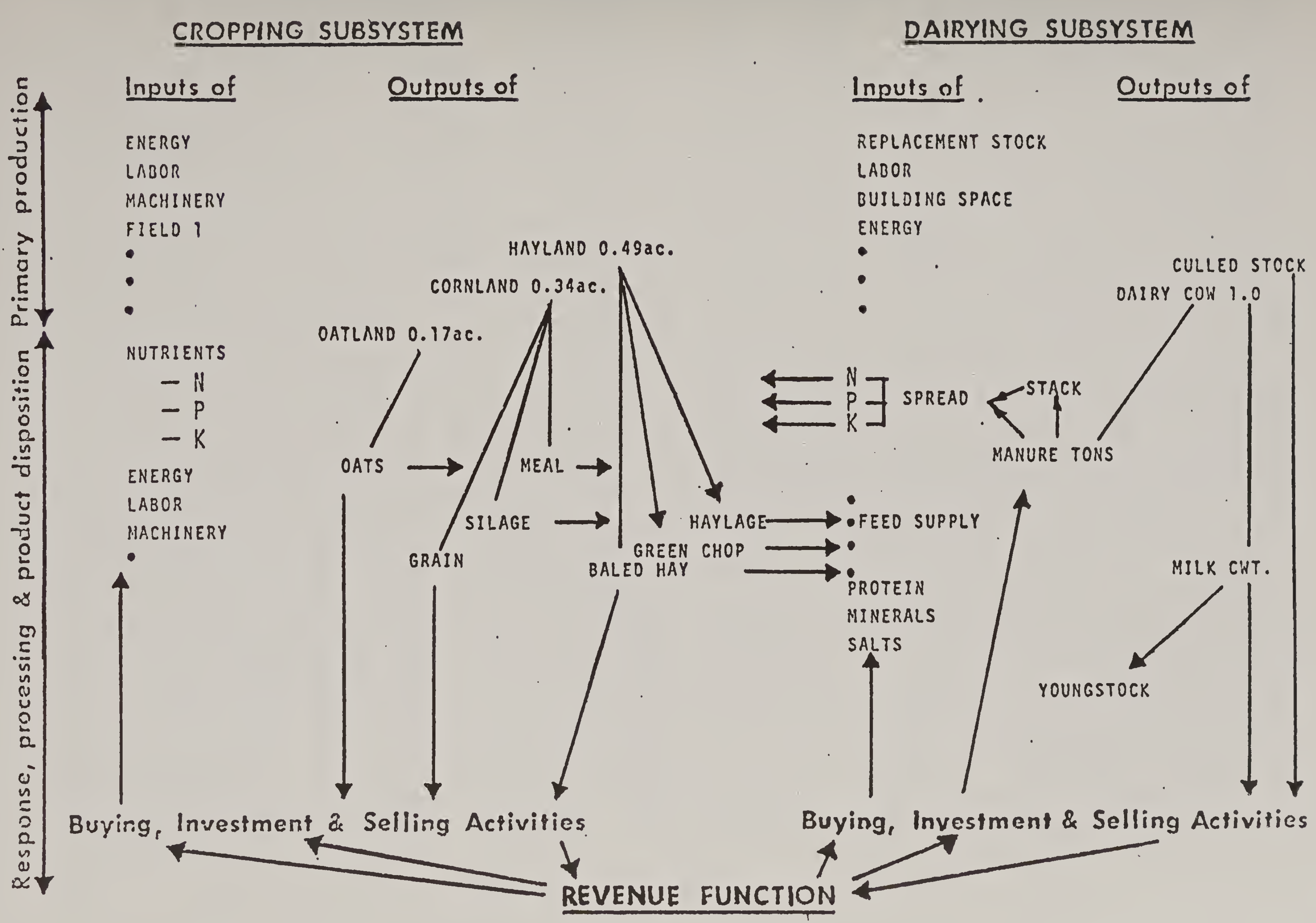
Farm activities transfer farm resources into farm outputs. The LP model, as illustrated in Figure 4, used to simulate the farm activities may be viewed as an ensemble of three interacting subsystems.

The Cropping Submodel

This model described how labor, machinery, land and fertilizer combine to produce crops. The cropping submodel contains seven alternative crop rotations. Each rotation requires a mix of inputs to produce specified quantities of crop outputs. The inputs include acres of land, tons of soil loss, kilowatts of energy, and hours of machinery and labor. The output is expressed as acres of cornland, oatland, and hayland.

The input-output relationship are based on farm interviews, with the exception of the soil loss input, which is computed using the Universal Soil Loss Equation (58). A constraint can be placed on total yearly soil loss. However, no limit was included in this analysis.

Figure 4--Production Interdependencies in a Mixed Crop-Livestock System



Source: (38)

The crop-producing process combines cropland acreage with nitrogen, phosphorus and potassium -- producing grain and forage (crop yield). Research listing the fertilization levels required to produce a given yield in Wisconsin while maintaining soil quality, is used as a guide for designing this section of the cropping model (50). It is assumed there are two sources of crop nutrients -- manure and commercial fertilizer. The two are interchangeable, except that a "starter" application of commercial nitrogen is required on corn. In addition, alfalfa is credited with nitrogen production.

Crops are often sold, but this option is not included in the program because this does not reflect the practice of the representative farm. Instead, all products raised on the farm are fed to livestock or stored for the future.

The Dairying Submodel

This submodel husbands cattle and replacement stock for milk production and animal sales. Corn, oats, and hay are mixed with feed supplements to form rations for the dairy herd.

There are four alternative combinations of forage and concentrate, which yield three levels of milk and manure production. Milk is sold and manure is used as an input in the cropping submodel.

In the dairying submodel, four methods are used to raise replacement stock. Each method requires an identical set of the following inputs: veterinary, labor, heifer barn space, breeding, and other livestock services. The four replacement-raising activities are distinguished from one another solely on the basis of how forage and grain requirements are satisfied.

Outputs of the replacement-raising activities include: revenue from sales of culled heifers; replacement stock for the dairy herd; and manure. To maintain a dairy herd of 80 cows --equal to the size of the interviewee's herd and which fully uses available barn space -- the size of the replacement herd must be 90 heifers. The latter figure is used by assuming a heifer culling rate of 12 percent, a cow-culling rate of 40 percent, and average age at first freshening of 26 months, and mortality rates for the following age groups: manure cows -- 2 percent; 12-24 months --1 percent; 3-12 months -- 2 percent, and 0-3 months --15 percent. The number of animals in the replacement herd, then, must be 12 percent more than the numbers of animals in the dairy herd (20).

Raising and milking dairy cows is similar to replacement-raising activities. Estimates of per cow livestock costs (expressed in liquidity terms), and yearly man-hours are included as inputs in each of the optional milking methods. The same source is consulted for the specification of a liquidity output, which results from the sale of culled dairy stock, for each activity. The size of that output depends on the assumptions that 40 percent of the dairy herd is culled annually, and that death loss claims 2 percent of the herd.

Any of the four rations can be used to produce 140 CWT of milk and 21 tons of manure per year from each cow (25). The farmer can also choose between a set of four rations to produce 12,000 pounds of milk and 18 tons of manure per year. Like the replacement rations, the milking rations are distinguished from one another by the way in which forage and grain requirements are met. Storage capacity sufficient to hold a year's supply of each type of grain and fiber must be provided, either by drawing on the farm's resources or by building such facilities. Similarly, each cow uses a certain amount of barn space.

The Financing Submodel

This submodel incorporates cash-flow considerations and long-term investment opportunities into the model. It is assumed that the farm must maintain a certain level of cash reserves at all times. Cash balances accumulate by marketing milk and surplus livestock. Input purchases are a drain on farm liquidity. Long-term investments can be financed by ten-year loans which carry an annual interest charge of 9.5 percent. Loan payments are deducted from gross farm income.

The farmer in the model must choose one of four manure management options. The cost and input requirements, and the amounts of nitrogen, phosphorus, and potassium made available to crops from a ton of manure handled by each method is shown in Table 2. These options are referred to as A, B, C or D. Under system A, manure is spread daily. This is the option used by the interviewed farmer as well as by his neighbors. In the other three options, manure is stored until fall, when it is disced into the fields: systems B, C, and D are distinguished from one another on three bases. First, each uses a unique type of storage capacity. Second, each requires different amounts of variable inputs (labor and machinery time, and energy) to store and spread a given amount of manure. Third, each delivers different quantities of nutrients to the soil from a unit of manure.

There are three activities corresponding to each management system. The first activity uses a loan to purchase the equipment and storage capacity required for an option. The amount of money needed to purchase a given collection of machinery and storage capacity must be large enough to handle the dairy herd's constant yearly manure output. The second activity uses machinery, labor, and energy to store manure. The third activity uses inputs

Table 2 --Description of Manure Management Options, Wisconsin Dairy Farm, White Clay Lake Region, 1977

Option[1/]	Additional Required Capital Expenditures	Investment Cost $	Per Ton Input Requirements[b/]			Per Ton Nutrient Delivery[c/]		
			Labor (hrs)	Machinery (hrs)	Energy (hrs)	N (lbs)	P (lbs)	K (lbs)
A	None	0[d/]	0.23	0.17	0.00	3.72	3.80	7.45
B	Spreader Piston Pump Covered Concrete Storage	38,217[d/]	0.15	0.10	0.88	8.95	3.80	7.45
C	Spreader Stack Plank Storage	21,870[d/]	0.20	0.10	0.60	7.22	3.80	7.45
D	Spreader Piston Pump Earthen Storage	22,479[d/]	0.15	0.10	0.88	6.33	4.00	7.90

a/Option A consists of the present practice of daily spreading and, consequently requires no additional investment. Options B, C, D represent alternatives to daily spreading; these systems are described in (56).

b/Source (56) farm interviews.

c/Source: (56); (50).

d/Investment cost for an option is the cost of all equipment not already on the farm required to implement the option.

to spread manure, thereby supplying the cropping subsystem with nitrogen, phosphorus, and potassium.

Each system's capital cost equals the cost of all machinery and storage capacity which is needed for that system and which is not already in place on the farm. The daily spreading method (option A) which was initially employed on the representative farm, requires no investment. On the other hand, the other three options require purchasing capital items listed in Table 2.

While management methods B, C, and D require higher capital and energy costs than option A, these systems require less machine and labor time to handle a ton of manure. Additionally, when option B, C, or D is used, more nutrients are obtained from a ton of manure than is the case where option A is used. A major reason for this increased nutrient delivery is that use of a storage facility allows a farmer to hold manure until that time of the year (during fall plowing, for instance) when manure can be better incorporated into the soil. When viewing option A's delivery, winter weather conditions and/or the presence of crops in the fields preclude the farmer from discing manure into the soil during most of the year.

As indicated, most farms in our study previously used manure handling option A. Therefore, status quo income is defined as the level of farm net income obtained when that system is used. Annual farm income was calculated using the LP optimization procedure, which chooses the mix of activities which maximizes pretax farm income subject to the farm's resource limitations.

CASE STUDY I: MIRROR/SHADOW LAKES

Waupaca Community Profile

Mirror and Shadow Lakes are located in the City of Waupaca, the county seat of Waupaca in east central Wisconsin. As is the case for the county, the City of Waupaca has experienced a higher growth rate than the State of Wisconsin and national metropolitan area averages (47). This is a relatively small town whose population has grown steadily since 1960 from 3,934 to 4,586, an approximately 17-percent increase over that 17-year period (46).

The economic base of the city of Waupaca has an unusually large percentage of manufacturing durables employment for such a small, rural town. More than 900 persons, 25 percent of city employment, are employed in jobs within this category, primarily in the Waupaca Foundry. Retail trade employs over 650 workers in the city, which represents 19 percent of city employment. Local government employees represent 16 percent of city employment, and manufacturing non-durables, which employs over 300 people in cheese processing, potato chip manufacturing and knitting mill, represents 10 percent of total city employment. Services employ more than 600 people (18 percent of city employment) primarily in retirement homes and tourist facilities. This is higher than the corresponding county, state or even United States employment percentage (16).

Since 1970 manufacturing employment has declined. Furthermore, while agriculture continues to play a significant role in the economic base of the county, the more than two decades trend of declining farm acreage and farm employment continues (47). The only growth sector for the local economy of Waupaca has been in services (47). The recent growth in service

jobs is due primarily to the increased number of retirement homes, summer cottages and substantial tourist activity within the county.

South Park--Mirror and Shadow Lake

Mirror and Shadow Lakes are both found within the corporate limits of the city. Mirror Lake has limited public access, is small, and drains directly into Shadow Lake.

Shadow Lake has had extensive public use for centuries. Menominee Indians regularly camped there and continued to camp there for years after the arrival of white settlers. Indian flints are still found around the lake.

In 1906, a group of women started a campaign to make Wright's Grove on Shadow Lake a park, but it wasn't until 1921 that the city council voted to acquire the property. A restrictive clause in the deed specifies that the property must be used by the city for park purposes only.

The recreation program for the city was started in the summer of 1946 with many activities taking place at South Park. In 1947 a complete Red Cross swimming instruction program was begun. In 1956 the Waupaca firemen built the concrete bath house for the park. In 1958 the parking lots, picnic tables, flower gardens and playground equipment were added. Attendance has fluctuated over the years between an estimated 40,000 and 75,000 recreators per year. 9/, 10/

9/A 40,132 user count was arrived at in the following manner. Lifeguards took a morning and afternoon count, added them together and doubled the sum to arrive at a daily user count for boaters, swimmers and fishers. This method had been employed by the Director of the Waupaca Department of Recreation, not only while he had worked in Waupaca but also during his employment in the Milwaukee Department of Recreation. These daily counts

However, as early as 1962 weeds began to appear in the swimming area on Shadow Lake. The water quality was still good but warnings of deterioration had begun to appear. The following is a chronology of the efforts that transpired and eventually resulted in the lake rehabilitation project to deal with this problem.

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were taken June 22 - August 22, 1978. Since the beaches were actually open from June 1 - September 30, estimates were provided for the two periods before and after the counts.

User counts (June 22 - August 22)	22,704
Estimated June 1 - June 21) 15 weekdays @100/day and 6 weekend days @400/day	3,900
Estimated (August 23 - September 30) 25 weekdays @ 60/day and 10 weekend days @ 240/day	3,900
Total for open water fishing, swimming, boating (1978)	30,504

A 1978 telephone survey of Waupaca residents revealed that 76 percent of the reported lake use was for swimming, open water fishing and boating, while 24 percent of uses went for picnics and ice-fishing during the winter. Since picnics and ice fishermen were not included in the daily user counts provided by the life-guards, their counts were expanded 24 percent. Total annual use of Shadow Lake for the year 1978 was estimated at 40,132. On-site interviews estimated that of this total approximately 15 percent were out-of-town users. Consequently, two representation rates were used; one based on 34,112 annual visits by Waupaca residents and the other based on 6,020 out-of-town users.

10/The 1968 count of 76,026 was determined in the same manner. The life guard counts for boaters, swimmers and fishers (June 1 - September 30) was 57,780 which was assumed as in the previous case to represent 76 percent of total lake use. Expanding to account for picnicking and ice-fishing brought the estimated, total annual use of Shadow Lake to 76,026. Two representation rates were again used; one based on 64,622 annual visits by Waupaca residents and the other based on 11,404 out-of-town users.

Project Chronology

1968-1969	Property owners on Mirror Lake, which was suffering from algae blooms and winter kills, asked the State to study both lakes and provide appropriate treatment.
1970	State and city officials discussed the matter.
1971	The city council formally passed a resolution requesting the Inland Lake Demonstration Project undertake a study and make recommendations. The study was paid for by the Upper Great Lakes Regional Commission and was conducted by the Wisconsin DNR and the University of Wisconsin Extension. The study concluded that 50 percent of the nutrient (phosphorus) inflow to the lakes was attributable to the storm sewers entering the lake. Storm sewer diversion and aeration of Mirror Lake was recommended.
1972-1973	An experimental hypolimentic aerator, for mixing the cold bottom waters with better quality surface water, was installed. The experiment was not successful.
1974	Shortly after the Wisconsin Legislature passed a new statute (Chapter 33) to permit local communities to undertake lake management, the city council created "The City of Waupaca Inland Lake Protection and Rehabilitation District".
January 1975	The new district applied for technical assistance requesting a design for a feasibility study. The need for a study was waived because of the previous research.
May 1975	The district submitted a proposed rehabilitation plan to DNR. Later that month public hearings were held on the plan.
Summer 1975	The district, through DNR, requested an Environmental Protection Agency (EPA) grant for construction work in rerouting storm sewers.
November 1975	The members of the lake district voted to tax themselves to pay the local share of the project cost.
January 1976	EPA committed funds to the project. Contracts were led by mid year. Cost shares amounted to:

EPA	50%	$215,000
DNR	30%	130,000
District	20%	85,000
TOTAL	100%	$430,000

July 1976	Construction began on diverting the storm sewers. The press and media covered the progress of the construction. The diversions were completed early in 1977.

1977 Aluminum sulfate was added to Mirror Lake to precipitate phosphorus in the water and seal off the nutrient rich sediment.

1977-1981 DNR and University of Wisconsin Extension evaluated the limniological, social and economic impacts of the project.

Lake Rehabilitation Project

As indicated above, previous studies had revealed that the primary source of nutrient (phosphorus) inflow was from storm sewer drainage directly into Mirror and Shadow Lakes. As a result the eutrophication process was hastened and a decline in water quality resulted. The eutrophication problem confronting the Waupaca lakes required several remedial steps. These consisted of storm water diversion, in-lake alum treatment, and aeration of Mirror Lake.

Storm Sewer Diversion

Prior to 1977 storm sewer drainage discharged directly into Mirror and Shadow Lakes. Mirror Lake received effluent from two separate storm sewers, and Shadow Lake from a stream into which storm sewer drainage entered. Approximately 60 percent of the watershed is urban with the resulting stormwater runoff conducted directly to the lakes.

The two storm drainage basins around Mirror Lake cover an area of 19.9 ha, primarily a residential area. These two basis had little interference from groundwater and exhibited characteristics of urban runoff.

The storm drainage basin entering Shadow Lake incorporated about 20.2 ha of developed urban land north and east of the lake and about 36.4 ha of undeveloped lowlands surrounding an intermittent stream which flowed into Shadow Lake.

In 1972 and the first five months of 1973, storm sewer runoff was measured. The storm sewer inputs for various chemical parameters resulting from this runoff are presented in Table 3.

Table 3--Total Storm Sewer Input for 1972

	Mirror Lake	Shadow Lake
	---kg---	
Total Phosphorus	9.8	14.4
Reactive Phosphorus (est.)	3.3	4.8
Total Nitrogen	57	6,146
Inorganic Nitrogen	28	62
Organic Nitrogen	29	84
Biological Oxygen Demand	269	340
Chloride	1,602	14,243
Sodium	775	6,714
Potassium	85	268
Calcium	290	3,447
Magnesium	149	1,724
Total Solids	7,648	28,576

Source: J. O. Peterson, unpublished data.

The larger amount of material entered via the Shadow Lake storm sewer, but this was a result of the larger area of the drainage basin. However, runoff coefficients were less for Shadow Lake than Mirror Lake because that part of the drainage basin for the Shadow Lake storm sewer was undeveloped land. As an example, the total phosphorus runoff coefficients were 0.5 kg/ha/yr. and 0.3 kg/ha/yr. for Mirrow and Shadow Lakes, respectively.

The nutrients entering the lakes via the storm sewers were potentially more detrimental to Mirror Lake than Shadow Lake. Vollenweider's permissible and dangerous phosphorus loading rates for lakes of this mean depth are $0.088 g/m^2/yr.$ and $0.172 g/m^2/yr.$, respectively (49). The phosphorus loading rates from the storm sewers alone were $0.192 g/m^2/yr.$ for Mirror Lake which exceeds Vollenweider's dangerous loading rate. The loading rate for Shadow Lake's storm sewer was $0.085 g/m^2/yr$, which approximately equals the permissible loading rate.

During 1976, all storm sewers entering Mirror and Shadow Lakes were diverted away from the lakes and into the Waupaca River. Studies have determined that the storm water diversion had insignificant impact on the Waupaca River.

A clear beneficial impact of the project is the improvement of water quality in Mirror and Shadow Lakes. The expected changes will have long-term beneficial effects on the water quality of the two lakes. Using the phosphorus residence model of Sonzogni, Uttormark and Lee, the new equilibrium in total phosphorus for Mirror Lake would be established in approximately eight years (39). The reduction in concentration was projected to drop from a mean annual concentration of 8/μg/l to 17μg/l. The addition of alum hastened the recovery and a new equilibrium was established at 23 μg/l within one year. If no action had been taken, the lakes would have been expected to further diminish as a recreational asset to the community.

Diverting storm sewers had the immediate effect of reducing the watershed size of both lakes. Mirror Lake's watershed was reduced by 59 percent to 13.1 ha. and the drainage basin for Shadow Lake was reduced to 56.7 ha., a reduction of 26 percent.

More important than watershed size reduction was the change in drainage area characteristics of the remaining drainage basin. Before the storm sewer diversion, 10 percent of Mirror Lake's watershed were streets and parking lots, while presently there are only two short streets in the basin. The number of roof tops has also been greatly reduced. At the present time, the drainage basin consists of residential lawns between the lake and the closest streets and city park land.

The percentage of street and parking lot area was smaller for Shadow Lake -- at six percent. Following storm sewer diversion, a parking lot at the city park remains in the watershed, and one street travels along part of one side of the lake shore, but most of the drainage basin is residential lawns, a cemetery, and a city park. The ratio of watershed area to lake surface area since the storm sewer diversion is 2.6 and 3.3 for Mirror and Shadow Lakes, respectively.

Changes in phosphorus and nitrogen loading rates prior to and following storm sewer diversion in Mirror Lake are noted in Table 4 Phosphorus loading rates were reduced 65 percent but nitrogen rates were reduced only 25 percent. Phosphorus loading rates in Mirror Lake presently are greater than Vollenwider's permissible rates, but are now below his dangerous levels (49).

Mirror and Shadow Lakes did not show any dramatic change in 1977, the first year following storm sewer diversion. This was not unexpected since a great deal of phosphorus was derived from the bottom sediments during periods when the bottom waters were anaerobic. It has been reported that diversion of a major nutrient source can improve the water

Table 4--Phosphorus and Nitrogen Loading Rates for Mirror Lake ($g/m^2/yr.$)

Phosphorus				
	1972	1973	1977	1978
Storm sewer	0.190	0.261	0	0
Groundwater	0.002	0.002	0.002	0.002
Diffuse runoff	0.060	0.097	0.046	0.069
Precipitation	0.053	0.016	0.055	0.061
Total	0.305	0.376	0.103	0.132

Nitrogen			
	1972	1977	1978
Storm sewer	0.968	0	0
Groundwater	1.184	1.184	1.184
Diffuse Runoff	0.586	0.445	0.677
Precipitation	0.868	1.139	1.000
Total	3.607	2.768	2.861

Source: J. O. Peterson, unpublished data.

quality of a lake (42). However, improvements are not always immediate. Lake Sammamish, located in King County, Washington, showed little sign of recovery for seven years following a one-third reduction in phosphorus loading, largely as a result of high phosphorus release rates during anaerobic conditions in bottom waters, but the lake later showed signs of recovery (53). It takes many years for lake problems to develop. It also takes many years for protection and rehabilitation actions to manifest themselves in clear lake improvements.

Following storm sewer diversion from Mirror and Shadow Lakes in December, 1976, external phosphorus loading rates were reduced 65 percent and nitrogen was reduced 25 percent in Mirror Lake.

Mirror Lake exhibited little change following storm sewer diversion in 1976 in regard to water chemistry or water transparency (18). However, bluegreen algae which were observed following rain storms in years prior to 1977 were not observed in 1977 (11).

Alum Treatment

Aluminum sulfate can be applied to lakes to precipitate phosphorus from the water column. The practice was first done in Scandinavia in the 1960's, with the first North American application being in Wisconsin Horseshoe Lake (34). Since then it has been used with varied success throughout the country.

The principle behind alum treatment is that the aluminum hydroxide combines with dissolved inorganic phosphorus to form a precipitation. The resulting floc settles to the lake bottom (9). A small amount of particulate phosphorus is also physically entrapped by the settling precipitate and carried with it to the bottom. Once on the bottom the alum layer acts as a seal preventing the migration of phosphorus from bottom sediments to the overlying waters.

An earlier study noted that during anaerobic conditions phosphorus concentrations became elevated in the bottom waters as a result of sediment release (34). Therefore, alum was applied to Mirror and Shadow Lakes not so much to remove phosphorus from the water column, but to prevent sediment release during anaerobic conditions.

Since the principal objective of alum treatment is sealing off the bottom sediments, only the area below the epilimnion was treated. The alum was injected at a depth of three meters, the bottom of the epilimnion. Alum has proven to be ineffective in sealing sediments in the mixing zone, i.e., epilimnion, therefore, in order to minimize costs only the area below the epilimnion was treated.

Prior to the application a three-meter contour was delineated and the lakes were divided into sections with buoys. Based on water volume in each section, the number of barge loads was calculated to achieve the appropriate alum concentration.

Mirror Lake received 40,900 kg of alum (1,718 kg Al) and Shadow Lake was treated with 81,000 kg of alum (3,400 kg Al) injected at the 3-meter level in both lakes. Assuming an even distribution of alum below this depth, the average aluminum concentration was 6.6 μg/l and 5.7 μg/l in Mirror and Shadow Lakes, respectively. Sedimentation traps in the bottom of Mirror Lake indicated that it took longer than 24 hours for all of the alum to reach the lake bottom.

Although the phosphorus level was higher in Mirror Lake than in Shadow Lake, the post treatment concentration was the same, about 20 μg/l. This concentration has been maintained through November 1979 in both lakes. The average annual phosphorus concentration in Mirror Lake prior to the alum treatment ranged from 88 μg/l to 93 μg/l, but following

treatment the annual mean was 20 μg/l, a reduction of 78 percent. The reduction is not as dramatic in Shadow Lake because the initial phosphorus concentrations were lower. Pretreatment concentration was 55 μg/l and posttreatment concentration was 23 μg/l, a reduction of 58 percent.

The reduction of dissolved reactive phosphorus (DRP) was even greater. The average concentration in Mirror and Shadow Lakes was 36 μg/l and 17 μg/l, respectively. In both lakes following ice-out in 1978 DRP was low (5 μg/l), especially in Mirror Lake and to a lesser extent in Shadow Lake this was a result of biological uptake as total phosphorus did not decline as much as DRP. Since the alum treatment, the average DRP concentration has been less than the detection limit of 4 μg/l. Only in late summer has DRP been detected in Mirror Lake.

A side effect of alum treatment is lowered alkalinity of pH. The alum application reduced the alkalinity and pH only near the level of the manifold outlet (3 m). The lowest alkalinity and pH observed was 159 μg/l and 6.8, and 105 μg/l and 6.5 in Mirror and Shadow Lakes, respectively. These levels were not low enough to cause problems.

Sediment cores were taken along a transect in both lakes before (1977) and after (1979) the alum treatment to determine the aluminum distribution. The cores were unsuccessful in determining the aluminum distribution. In most instances aluminum concentrations were higher in 1977 than in 1979. Often the maximum aluminum concentration was in the top core slice both in the pretreatment and posttreatment core. Aluminum concentrations were higher in the deeper waters, but this would be expected without the alum treatment since aluminum is usually associated with finer particles which tend to settle in the deeper waters (7).

The applied aluminum failed to show up in the cores because the addition was small compared to the background concentrations. Since background levels are high it would not be expected that alum treatments in these and similar lakes would be detrimental to benthic invertebrates.

The anticipated costs for aluminum sulfate treatment were $21,000. The actual cost for alum treatment totalled $8,771, and was itemized as follows: chemical cost equalled $6,207 and application cost equalled $2,564.

In sum, the alum treatment reduced total phosphorus from an annual mean of 90 μg/l to 20 μg/l in Mirror Lake and in Shadow Lake from 55 μg/l to 23 μg/l. The maximum phosphorus concentrations in the bottom water have been reduced an order of magnitude. The DRP concentrations have continuously been below 4 μg/l since alum treatment.

Following alum treatment, nitrogen levels have not changed significantly. Ammonium-N concentrations in excess of 3 μg/l are still observed in bottom waters. The one significant change was the increased concentrations of inorganic nitrogen (primarily in the form of NO_3-N) in the spring of 1979.

Water transparency increased in both lakes following alum treatment, but reverted back to pretreatment levels and actually decreased in Mirror Lake in the summer of 1979. This decreased transparency seemed to be a result of increased background attenuation of light and not increased algal biomass.

Aluminum sulfate treatments are effective in phosphorus control by sealing bottom sediments thus preventing phosphorus migration during anaerobic conditions. This treatment should only be considered in well stratified lakes. It seems necessary, however, to reduce the external phosphorus sources to an acceptable level prior to an alum treatment, otherwise benefits derived as a result of treatment probably will be short-lived.

Aeration (Artificial Circulation)

Studies in 1972-1973 determined that Mirror Lake was probably meriomictic (it did not mix) resulting in a permanent anoxic environment in the bottom waters (40). In order to replenish the oxygen the lake is being artificially circulated before ice formation in the fall and following ice-out in the spring.

Artificial circulation is one of the most efficient lake aeration techniques. Aeration is a common method of alleviating the problem of dissolved oxygen depletion and has a long history of use in lakes and reservoirs. Although it is generally viewed as a cosmetic treatment of the symptons of eutrophication, it also has the potential for improving the nutrient status of lakes and retarding or reversing the process of eutrophication. The objective of most aeration projects, however, is limited to improve dissolved oxygen conditions for the fishery.

In Mirror Lake, total circulation was undertaken to increase the dissolved oxygen content of the bottom waters by mixing the entire lake water volume.

The aeration unit at Mirror Lake consists of a compressor on the lake shore and 2-inch plastic pipe from the compressor to the deep area of the lake. The pipe was laid along the lake bottom and weighted with cement blocks. The end of the pipe in the lake has three 3/8-inch holes spaced about nine inches apart. The compressed air itself does not aerate the water. The unit only mixes the water column, and oxygen is distributed throughout the lake as a result of the mixing action with aeranated water near the surface. The compressor is usually run two to three weeks in the spring and again in the fall.

Because the compressor started late in the year 1977, some concern was expressed about creating an open-water hazard. At a time when the lakes in the area were developing a total ice cover, the compressor was creating a two-acre area of open water. Consequently, the compressor was turned off after three days. Within the three-day period, the lake was totally mixed; however, the introduction of oxygen-demanding substances from the anoxic water that was mixed into the overlying oxic waters caused an initial dissolved oxygen depression throughout the entire lake. At the time the compressor was shut off, the weighted average dissolved oxygen for Mirror Lake was 2.6 μg/1. Although oxygen levels were low during ice cover (generally 1.0 μg/1), a fish kill was not recorded.

A consequence of spring mixing in Mirror Lake is the increased temperatures in the bottom waters on the onset of stratification in May. Before mixing, bottom water temperatures were generally about $6^{o}C$, but with mixing these temperatures increased to $10^{o}C$.

The result of artificially circulating the lake in the spring and fall is a substantial increase in the dissolved oxygen concentrations in Mirror Lake before ice cover and the prevention of winterkill conditions at a relatively low cost. The anticipated costs for artificial circulation was budgeted at $3,000. The actual cost for this portion of the project was $1,937.

Water Quality Indices

The preceeding discussion of the physical intervention of Mirror and Shadow Lakes and the associated impacts on the various water quality parameters indicates that a change has transpired. The question is, how does this information translate into a measure that can be incorporated into the economic analysis? Recall in the property value impact model and recreation model the relevant indices to be used as the independent water quality variables were the PWQI and the LCI. Consequently, the physical scientists were asked to equate the information on the various measures of water quality to the corresponding PWQI and LCI.

Experts Estimation of Perceived Water Quality Index (PWQI)

To estimate the stream of benefits over the life of the project, annual estimates of the seven water quality parameters with and without the project are necessary. These estimates were provided by the DNR limnologist acting as the principal investigator in EPA Grant #804687-01: The Limnological Evaluation of the Lake Restoration Project At Mirror and Shadow Lakes. Estimates from the above study were provided with the following qualifications:

1. Accurate estimates can only be generated by computer simulation models, and even then such models can't take into full account the impact of unique and unforeseen lake characteristics. Since neither the time nor funding was available to do simulation work, the estimates provided represent only approximations by the limnologist based on his experience and expertise.
2. Since algae blooms on Mirror and Shadow Lakes are not considered "typical", the visible algae problems are based on a fall-winter-spring period only.

The with and without project estimates of the seven water quality parameters at their corresponding water quality index values over the life of the project are provided in Tables 5 and 6 for Mirror and Shadow Lakes, respectively.

For Mirror Lake the greatest improvements are realized in the algae and wildlife support parameters in the first four years with the project. Without the project the water clearness and recreational capacity parameters deteriorate after 30 years. For Shadow Lake the impact of the project is primarily to maintain present water quality of the lake. Only the algae and wildlife support capacity parameters show any improvement after four years with the project. Without the project, water clearness, algae, odor, wildlife support and recreational capacity parameters all deteriorate after 30 years, and this wildlife support parameters continues to deteriorate further in the last year considered in this project.

Lake Condition Index (LCI)

The LCI was estimated for Shadow Lake, again by the limnologist researching the water quality impacts, to allow comparison of the water quality, and throughout the project period for both the with and without project conditions. Since only property values and no recreation benefits will be calculated for Mirror Lake, the LCI for Mirror Lake is not presented.

LCI totals for Shadow Lake indicate continual improvement with the lake protection/rehabilitation project. As am example, the before the project LCI is 10. In 50 years without the lake project the LCI rating is forecasted to be 20. With the project, the 50-year projection is an LCI of 6. The years in which changes occur are presented in Table 7. It is assumed that after the last change in 2010 the water quality will stabilize for the duration of the analysis period.

Table 5 --Estimates of Water Quality Parameters for Mirror Lake

Water Quality Parameter	Initial Year 1976	Year of Change 1977	1978	1979	2001	Final Year 2010
Industrial Waste						
With Project	A					A
Without Project	A					A
Debris						
With Project	A					A
Without Project	A					A
Clearness						
With Project	B				B	B
Without Project	B				C	C
Algae						
With Project	D	C	B	A		A
Without Project	D	D	D	D		D
Odor						
With Project	B			A		A
Without Project	B			B		B
Wildlife Support						
With Project	D	C	B	A		A
Without Project	D	D	D	D		D
Recreation Opportunity						
With Project	A				A	A
Without Project	A				B	B

Source: Wisconsin State Department of Natural Resources
(Doug Knauer, Limnologist)

Table 6--Estimates of Water Quality Parameters for Shadow Lake

Water Quality Parameter	Initial Year 1976	Year of Change 1979	Year of Change 2001	Final Year 2010
Industrial Waste				
With Project	A			A
Without Project	A			A
Debris				
With Project	A			A
Without Project	A			A
Clearness				
With Project	B		B	B
Without Project	B		C	C
Algae				
With Project	C	B	B	B
Without Project	C	C	D	D
Odor				
With Project	A		A	A
Without Project	A		B	B
Wildlife Support				
With Project	B	A	A	A
Without Project	B	B	C	D
Recreation Opportunity				
With Project	A		A	A
Without Project	A		B	B

Source: Wisconsin State Department of Natural Resources
(Doug Knauer, Limnologist)

Table 7--Shadow Lake LCI with and without project.

Year	LCI (With Project)	LCI (W/o Project)	LCI Difference
1977	10	10	0
1979	9	10	1
1980	8	10	2
1981	7	10	3
1982	6	10	4
1999	6	12	6
2000	6	14	8
2001	6	16	10
2002	6	18	12
2009	6	18.7	12.7
2010	6	20	14
2026	6	20	14

Source: Wisconsin State Department of Natural Resources. (Doug Knauer, Limnologist)

Economic Impacts

To properly estimate the economic impacts associated with a project there are several issues that must be determined, viz., what is the relevant period of analysis, and what is the proper discount rate?

According to the Water Resources Council's Principles and Standards, the period of analysis should be the lesser of: (1) the period of time over which the project will serve a useful purpose; or (2) the period of time when further discounting of beneficial and adverse effects will have no appreciable results on design (51). Since the property value model is specified in such a fashion that expected future benefits (costs) are capitalized in the property value at the time of a water quality change, then the appropriate time period is that in which something either positive or negative occurs either with or without the project that would impact the affected property values. Thus, when estimating impacts using the property value impact model the relevant time period, as determined by water quality experts, is 34 years.

In the estimation of recreational benefits the relevant time period is 50 years. When using the recreation model it is necessary to estimate and discount each year's impact. Consequently, it would be necessary to invoke the second condition specified in the Principles and Standards, e.g., at 50 years in the future a dollar discounted at 8 percent is only worth 2 cents.

In order to determine the economic viability of a particular project, one must reduce the time stream of costs and benefits to a single number. This aggregation is accomplished by computing the net present value of a

project, and as indicated above, the rate of discount is a crucial parameter in this calculation. Theoretically, the correct discount rate is that rate which, when applied to future costs and benefits, yields their actual present social values. In other words, the proper rate is the rate at which society as a whole is willing to trade off present for future costs and benefits. There are several schools of thought regarding how one translates this definition into the appropriate, operational discount rate. Two measures of the discount rate that normally reflect the extremes are the opportunity cost of capital and the social time preference. Both of these rates will be employed to provide us with a sensitivity analysis on the impact of alternative interest rates.

The opportunity cost of capital reflects the value of the productivity that would have occurred had the resources not been taken out of the private sector of the economy by the government for the project. The cost of capital is affected not only by this productivity consideration but also by the degree of risk involved since a lender would charge a higher rate of interest to those less likely to repay. The prime lending rate is perhaps the best indicator of the current opportunity cost of capital. A rate of 15 percent was selected to reflect the higher costs of capital that now exist in todays financial markets.

The alternative viewpoint states that the government provides an intergenerational transfer of benefits. It acts as a trustee of the future. Thus, in evaluating public investment projects the government imposes a lower discount rate to provide for future generations. This viewpoint also questions some of the assumptions on which the previous approach is built. The most questionable assumption is that a government decision to implement a project causes a transfer of funds from the private

to the public sector equal to the cost of the project. In the immensely complicated government budgetary process, the current appropriation of each agency is determined in large measure by its previous appropriation, current government fiscal and monetary policy and the administration goals. Thus, a specific project may have little or no effect on the size of the allocated budget. Furthermore, since the size of the total government budget is dictated, at the margin, by broad economic policy objectives, more for one agency necessarily means less for another. Consequently, a project is in direct competition for funds with alternative projects of the same agency and indirectly with projects of other agencies. Thus, the base of reference for the analysis of a project should be the alternative use of funds within the government sector, not funds within the private sector. This line of thinking supports a lower social discount rate than that of the opportunity cost of capital position. Accordingly, the Principles and Standards specifies that the official discount rate for water related projects is set by the Water Resources Council, which for fiscal year 1980 set the rate at 7 1/8 percent (51).

In addition to these considerations project impacts will be measured by estimating the project condition with and without the project. This is necessary as changes will occur in the absence of the project and these must be taken into account.

Property Value Impacts

The application of the property value impact model presented earlier requires the following information:

(a) Annual estimates by a water quality expert of changes expected in the seven water quality parameters both with and without the project (provided in Tables 5 and 6;

(b) The effective time period of the analysis (34 years - see discussion above);

(c) The percentage of shoreline that is accessible to the public;

(d) The maximum distance-from-the-lake for the residential area considered to be impacted by the park;

(e) The number of homogenous zones within the impact area;

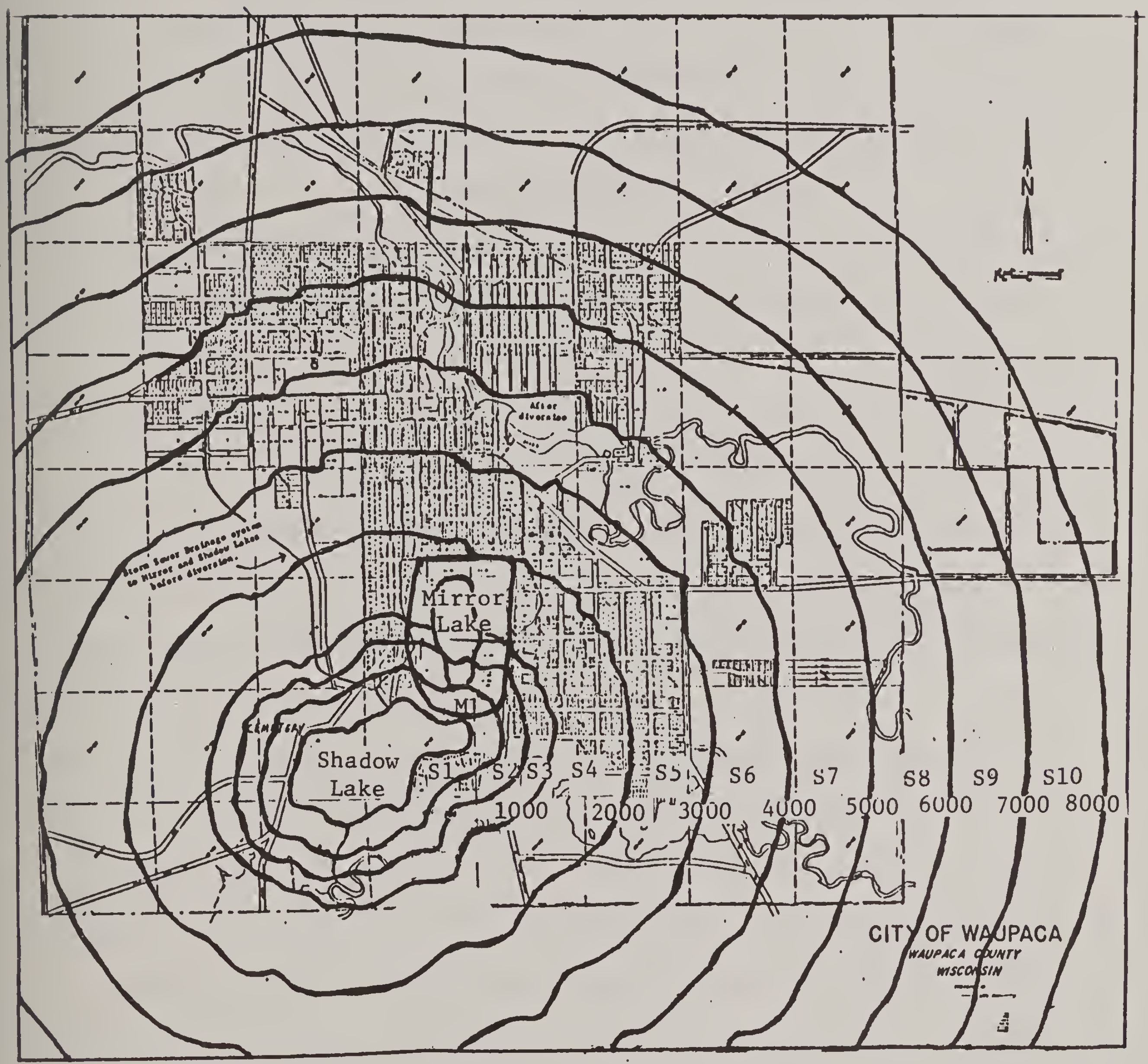
(f) The property development growth rate; and

(g) The property values for residential properties within the impacted area and their distance from the lake.

Since (a) and (b) have already been discussed the following will be directed to (c) thru (g).

Equation (3) specifies that the percentage change in property value is a function, among other things, of the property's straight line distance from the lake, i.e., $\Delta P\%_d = b_o + b_1 (1/DW_d)$. To simplify this calculation the total area to be impacted by the project for each lake has been divided into distance-from-the-water zones (d), as indicated on Map 1. Use of the simple step function, where each step is evaluated on the basis of the average distance to each distance-from-the-water zone, offers an operationally useful and accurate approximation of the continuous function's integration. This approach assumes that change in $\Delta P\%$ will be calculated for each distance zone d. Since Mirror Lake is bordered almost entirely by private homes and has very limited public access and use of the lake, the beneficiaries of the

Map 1--Distance from the Water Zones



improvements in water quality for that lake were restricted to those residential properties that border on the lake. Consequently, only one distance zone (M1 on the map) was used for Mirror Lake. Shadow Lake, on the other hand, has extensive public access and facilities for varied public use, so its impact area was assumed to be all residential home owners in the city of Waupaca. Consequently, ten distance-from-the-water zones (S1-S10 on the map) were used.

The benefit calculation for a given year (in this case the equation pertains to residential properties impacted by Shadow Lake) is the following:

$$RPB = \sum_{d=1}^{10} INCR\Delta P\%_d * TRPV_d * (1+GR_d)^i \tag{23}$$

where RPB represents residential property benefits; $INCR\Delta P\%_d$ represents the incremental percentage change in the value of properties in distance zone d for that year; $TRPV_d$ is the sum total of the residential property values for zone d, and $(1 + GR_d)^i$ represents an annual growth factor to account f the expected future development of vacant land in that zone. The growth factor, GR, represents the projected percentage change in population in Waupaca between 1977 and 2000 (<u>52</u>). It is assumed that the increase in residential homes is proportional to the projected percentage increase in population. Furthermore, it is assumed that the twenty-three year projection of 22 percent population increase will apply to the thirty-four year period of analysis used for this project (1976-2011) (<u>52</u>). This does not seem to be an unreasonable assumption once a leveling off effect is taken into consideration.

Since vacant land for residential development is primarily available on the northern and western parts of the city, only those distance zones which contain portions of this vacant land will have a growth factor. Consequently, only the distance zones S4-S10 contain a non-zero GR_d. In order that the total growth rate over the thirty-four year period be equal to 22 percent, the annual growth rate is estimated to equal .0058. For the i^{th} year the total growth rate would be $(1.0058)^i$.

Theoretically, the appropriate measure of residential property values is the market value. The problem with using market values is that in a given distance-from-the-water zone the average market value of properties sold that year may not be an accurate measure of the actual average value of <u>all</u> the properties there, which would necessarily lead to an inaccurate estimation of the property benefits for that zone. Consequently, an adjusted assessed value of residential property for the year 1976 was used. The adjustment factor was determined by the inverse of the average assessment ratio:

$$\text{Average Assessment Ratio} = \left[\sum_{i=1}^{N} \left(\frac{\text{assessed value}_i}{\text{market value}_i} \right) \right] / N \qquad (24)$$

where N equals the number of properties sold in zone d in 1976. The adjusted assessment value total (i.e., the sum of the assessed value for zone d multiplied by the inverse of the average assessment ratio) serves as a close approximation of the total market value of the residential properties in that zone. These values are provided in Table 8 for the city of Waupaca.

Table 8--Waupaca Property Values by Distance-From-Water Zones, 1976

Lake	Distance-From-Water Zone (See Map 1)	Max. and Min. Distance Range of Zone (feet)	Average Distance of Zone (feet)	Property Value Zone Totals	Annual Growth Factor (GRd)
Mirror	M1	0-400	200	$1,403,500	-0-
Shadow	S1	0-400	200	868,600	-0-
Shadow	S2	400-700	550	453,400	-0-
Shadow	S3	700-1,000	850	1,088,400	-0-
Shadow	S4	1,000-2,000	1,500	4,450,560	.0058
Shadow	S5	2,000-3,000	2,500	7,011,700	.0058
Shadow	S6	3,000-4,000	3,500	5,343,540	.0058
Shadow	S7	4,000-5,000	4,500	5,902,300	.0058
Shadow	S8	5,000-6,000	5,500	1,892,880	.0058
Shadow	S9	6,000-7,000	6,500	818,900	.0058
Shadow	S10	7,000-8,000	7,500	282,000	.0058

By using the annual $PWQI_{Exp}$ ratings developed on a with or without project basis in Tables 5 and 6 and equations (3), (5), (6), and (8 from the empirical model, the total annual percentage change in property values ($\Delta P\%$) can be calculated for the two lakes. Since property value impacts are capitalized in the year a water quality change takes place, it is necessary to determine the annual incremental increase. The annual incremental percentage change in property values ($INCR\Delta P\%$) for year (i) is calculated in the following manner:

$$INCR\Delta P\%_i = \Delta P\%_i - \Delta P\%_{i-1} \qquad (25)$$

The total and incremental calculations for Mirror Lake are presented in Table 8 . The total and incremental calculations for Shadow Lake are presented in Tables 9 and 10 , respectively. For Mirror Lake the changes in property values occurred in the second, third, fourth and twenty-fifth year of the project. For Shadow Lake the changes occurred in the third, twenty-fifth and thirty-fourth year of the project. For both lakes the amount of change decreased through time, and for Shadow Lake the amount of change also decreased with increasing distance-from-the-lake as expected.

In Tables 11 and 12 the annual $INCR\Delta P\%$ is multiplied by the appropriate zone total of property values to give in dollar terms the incremental, annual increase in property values for each lake.

In Table 13 these incremental, annual increases in property values are discounted back to 1977 using both the 7-1/8% and the 15% discount rates and the sum to give the total discounted property value benefits expected to occur for each lake as a consequence of having undertaken the

Table 9 --Total and Incremental Annual Percentage Change in Property Values for Mirror Lake

Year	a/ $PWQI_{Exp}$	b/ $PWQI_{Res}$	c/ b_1	d/ b_o	e/ $\Delta P\%$ for M1	INCR $\Delta P\%$ M1
1977	7.77	0.0	0.0	0.0	0.0	0.0
1978	29.76	4.50188	4097.8247	-10.244561	10.244	10.244
1979	43.65	10.93295	6340.7752	-15,851938	15.852	5.608
2001	61.80	19.33640	8394.2205	-20.985551	20.986	5.134

a/ $PWQI_{Exp}$ is taken from Table 5.

b/ $PWQI_{Res}$ is calculated according to equation(8) ;$PWQI_{Res} = -24.778 + .463$

$(PWQI_{Exp}) = 15.501$ (PA) where PA = 1

c/ b_1 is calculated according to equation (5)

$$b_1 = e^{6.398}(PWQI_{Res})^{.492}\ e^{1.180(WBT\ Lake)}$$

d/ b_o is calculated according to equation (6)

$$b_o = -b_1(DW_{max}) \text{ where } DW_{max} = 400$$

e/ $\Delta P\%$ is calculated according to equation (3)

$\Delta P\% = b_o + b_1\ (1/\overline{DW}_j)$ for the one distance zone;

$\overline{DW}_j$ is the average distance from the lake to the zone.

Table 10.--Total Annual Percentage Change in Property Values for Shadow Lake

Year	a/ $PWQI_{Exp}$	b/ $PWQI_{Res}$	c/ b_1	d/ b_o	e/ ΔP% for zone S1	ΔP% for zone S2	ΔP% for zone S3	ΔP% for zone S4	ΔP% for zone S5	ΔP% for zone S6	ΔP% for zone S7	ΔP% for zone S8	ΔP% for zone S9	ΔP% for zone S10
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	12.3	11.9189	6615.9432	-.8269929	32.253	11.202	6.956	3.504	1.819	1.063	0.643	0.376	0.191	0.055
2001	54.19	31.31397	10641.105	-1.3301381	51.875	18.017	11.189	5.764	2.926	1.71	1.034	0.605	0.307	0.089
2010	60.64	34.30032	11128.849	-1.3911061	54.253	18.843	11.702	6.028	3.06	1.788	1.082	0.632	0.321	0.093

a/ $PWQI_{Exp}$ is taken from Table 6.

b/ $PWQI_{Res}$ is calculated according to equation (8): $PWQI_{Res} = 024.778 + 0.463\ (PWQI_{Exp}) + 15.501\ (PA)$ where PA = 2

c/ b_1 is calculated according to equation (5): $b_1 = e^{6.398}(PWQI_{Res})^{0.492} e^{1.180}$ (WBT Lake)

d/ b_o is calculated according to equation (6): $b_o = -b_1\ (DW_{max})$ where $DW_{max} = 8{,}000$.

e/ ΔP% is calculated according to equation (3): $\Delta P\% = b_o + b_1\ (1/\overline{DW}_j)$ for each distance zone. $\overline{DW}_j$ is the average distance from the lake to each distance zone.

Table 11 --Incremental ΔP% Calculations - Shadow Lake [a/]

Year	INCR Δ P% S1	INCR Δ P% S2	INCR Δ P% S3	INCR Δ P% S4	INCR Δ P% S5	INCR Δ P% S6	INCR Δ P% S7	INCR Δ P% S8	INCR Δ P% S9	INCR Δ P% S10
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	32.253	11.202	6.956	3.584	1.819	1.063	0.643	0.376	0.191	0.055
2001	19.622	6.815	4.233	2.18	1.107	0.647	0.391	0.229	0.116	0.034
2010	2.378	0.826	0.513	0.264	0.134	0.078	0.048	0.027	0.014	0.004

a/ Incremental ΔP% figures are derived from ΔP% figures in Table 10.

i.e., $INCR\Delta P\%_i = \Delta P\%_i - \Delta P\%_{i-1}$.

Table 12 --Incremental Annual Increase in Property Values - Mirror Lake

Year	a/ INCRΔP% for M1	b/ Property values by zone	Increase in Property value
1977	0.0	$1,493,500	$ 0
1978	.10244	1,403,500	143,774
1979	.05608	1,547,274	86,171
2001	.05134	1,634,045	83,891

a/ INCR P% for MI is taken from Table 9.

b/ Initial property value is taken from Table 8. Subsequent changes attributable to water quality impacts are then added.

Table 13--Incremental Annual Increase in Property Values - Shadow Lake

Zone and Year [a]	INCRΔP% for Zone ___ [b]	Property Value for Zone ___ [c]	Total Incremental Change for Zone ___ [d]
	---Percent---	---Dollars---	
Zone 1:			
1977	.00000	868,600	0
1979	.32253	868,600	280,150
2001	.19622	1,148,750	0
2010	.2378	1,374,158	32,677
Zone 2:			
1977	.00000	453,400	0
1979	.10202	453,400	50,790
2001	.68150	504,190	34,361
2010	.00826	538,551	4,448
Zone 3:			
1977	.00000	1,088,400	0
1979	.06456	1,088,400	75,709
2001	.04233	1,164,109	49,277
2010	.00513	1,213,386	6,225
Zone 4:			
1977	.00000	4,450,560	0
1979	.03584	4,502,336	161,364
2001	.02180	5,296,470	115,463
2010	.00264	5,767,404	15,226
Zone 5:			
1977	.00000	7.011,700	0
1979	.01819	7,093,272	129,026
2001	.01107	8,202,218	90,800
2010	.00134	8,837,725	11,843
Zone 6:			
1977	.00000	5,343,540	0
1979	.01063	5,405,705	57,463
2001	.00647	6,204,409	40,143
2010	.00078	6,654,711	5,191
Zone 7:			
1977	.00000	5,902,300	0
1979	.00643	5,970,965	38,393
2001	.00391	6,819,497	26,664
2010	.00048	7,295,836	3,502
Zone 8:			
1977	.00000	1,892,880	0
1979	.00376	1,914,901	7,200
2001	.00229	2,181,914	4,897
2010	.00027	2,330,225	629
Zone 9:			
1977	.00000	818,900	0
1979	.00191	828,427	1,582
2001	.00116	942,410	1,093
2010	.00014	1,005,403	141
Zone 10:			
1977	.00000	282,000	0
1979	.00055	285,280	157
2001	.00034	324,143	110
2010	.00004	345,544	14

a/ 1977 reflects initial water quality conditions and 1979, 2001, and 2010 are the years in which a water quality change occurs.

b/ INCRΔP% data taken from Table 11.

c/ Initial property values by zone are taken from Table 8. Subsequent changes attributable to water quality increases and growth are then added.

d/ Total incremental change in property values is the product of INCRΔP% and relevant property value for that zone.

Table 14--Discounted Incremental Annual Property Value Increases to 1977

Year	Mirror Lake		Shadow Lake	
	Discounted at 7-1/8%	Discounted at 15%	Discounted at 7-1/8%	Discounted at 15%
	---Dollars---			
1978	134,212	125,021	---	---
1979	75,612	65,608	698,718	606,267
2001	16,099	2,928	112,898	20,532
2010	---	---	8,261	791
Total	$225,923	$193,557	$819,877	$627,590

lake rehabilitation project. The total discounted property value increase for Mirror Lake is $225,923 and $193,557, using a 7-1/8 and 15 percent discount rate, respectively. For Shadow Lake, the total discounted property value increase using a 7-1/8 percent discount rate is $819,877 and $627,590 using a 15 percent discount rate. The total benefits are therefore $1,045,800 and $821,147 for the two discount rates.

Direct Project Costs

The direct monetary costs of the project includes the costs of storm sewer diversion, purchase and installation of the compressor for aeration, annual operating and maintenance costs for the compressor and alum treatment costs. In order to compare project costs with project benefits, the costs have been discounted to 1977. Using the 7-1/8 percent interest rate, the total project costs expressed in 1977 dollar terms are $439,872 and $469,650 when the 15 percent interest rate is used.

Equity

The foregoing analysis has revealed that benefits, as determined by the property value impact model, are in excess of the costs, whether discounted at 7-1/8 or 15 percent. Although this information does not provide a complete picture regarding project efficiency due to the omission of non-local recreational benefits, it does provide insight to the incidence of local benefits and costs.

Distributional equity refers to distribution of benefits and costs associated with a project. There are significant equity considerations involved with the Mirror-Shadow Lakes restoration project that are of interest. It is assumed here that the federal, state, and local cost shares have been appropriately determined and, therefore, only the distribution of the local cost share will be examined.

Local revenues were raised by levying a two-year 0.9 mill tax to provide funds to cover the 20 percent of the project costs. Consequently, each residential property owner paid for a portion of the project according to the before project property value, e.g., approximately $90 for a $50,000 home. However, the well-being that each residential property owner enjoys as a result of the project does not vary in the same manner as the amount of taxes each had to pay.

In the case at hand there exist two reasons for the discrepancy. First, the impact on property values diminishes as distance from the lake increases. This is demonstrated in Table 15 which compares the percent of project benefits received to percent of project costs paid by zone. In Zone 1 it is estimated that approximately 35 percent of the project benefits accrue, yet only 3 percent of the project costs were paid by property owners in this zone. Benefits accrued exceed costs paid, at a diminishing rate, through zones 1-4, and costs exceed benefits in zones 5-9. Consequently, the increases in well-being of residential property owners closer to the lake appears to come at the expense of the well-being of the property owners situated farther from the lake.

The second reason, and one probably unique to this case, is that Mirror Lake-front property owners enjoy both the benefits of water quality improvements made on that lake and those made on Shadow Lake, while other property owners enjoy only the benefits from improvements made on Shadow Lake. The reason for this is that public access on Mirror Lake is highly restricted but not so on Shadow Lake. The total discounted property value increases enjoyed exclusively by Mirror Lake-front property owners due to improvements made in the water quality on Mirror Lake is $225,923 and the

'Table 15--Benefit and Cost Incidences for Waupaca Residential Property Owners to Shadow Lake Rehabilitation Project

Zone	Average Distance From-the-Water of Zone (Feet)	Residential Property Values 1976 Zone Totals (Dollars)	Project Benefits Received (Percent)	Project Costs Paid (Percent)
1	200	868,600	35.5	3.1
2	550	453,400	6.2	1.6
3	850	1,088,400	9.3	3.9
4	1,500	4,450,560	21.0	15.8
5	2,500	7,011,700	16.0	25.0
6	3,500	5,343,540	7.0	19.0
7	4,500	5,902,300	4.9	21.0
8	5,500	1,892,880	0.9	6.7
9	6,500	818,900	0.2	2.9
10	7,500	282,000	0.0	1.0
		TOTAL	100.0	100.0

The flow of benefits will vary considerably depending on the elasticity of the demand curve, the change in water quality, and number of users, and the discount rate used to discount benefits (costs). The first of these is dictated by the data and estimation procedure used and therefore will not be subject to change. The projections concerning water quality are based upon water quality experts judgments and are assumed correct. However, the last two factors, user number and discount rate, are subject to wide variations and require special consideration. This was accomplished through the use of sensitivity analysis.

User figures were available from previous Waupaca Recreation Department user counts. As one might expect these varied widely from year to year because of fluctuations in the weather. In 1978, the year following project completion had many rainy and overcast days which resulted in only 40,132 users. However, in 1968, a very hot summer, the user population was 76,026. These figures will form the relevant bounds for the sensitivity analysis.

The flow of benefits are spread over the entire life of the project. To compare this time stream of project benefits with the project costs, they must be discounted to their present value, as was done with the property value impacts.

The total recreational benefits attributable to water quality changes were estimated by the procedure outlined above. The annual with and without impacts over the 50-year duration of the project are presented in Tables 16 and 17 for the two user populations. The lowest estimate of total discounted recreational benefits based on 40,132 users and the 15 percent discount rate was $252,172 and the highest estimate based on 76,026 users and the 7-1/8 percent discount rate was $1,349,818. Since the

total discounted property value increases enjoyed by Mirror Lake-front property owners due to improvements in the water quality on Shadow Lake is $105,950. Thus, approximately 31 percent of total project benefits are enjoyed by Mirror Lake-front property owners. It might be argued that this is an overestimation of benefits for Mirror Lake property owners as it is reasonable to assume they may not fully value the benefit flow from the enhancement of Shadow Lake because of the more accessible substitute they have in Mirror Lake. Unfortunately, there does not exist enough information to determine the extent of this bias. However, this does not refute the argument regarding the distribution of benefits and costs, only the degree of this distribution.

Since local revenues were raised through a two-year increase in the property tax mill rate, the percentage of local project costs born by the Mirror Lake-front property owners is equal to the sum of their assessed property values divided by the sum of all assessed property values for the City of Waupaca, which is considered the impact area for this project. The percentage of local costs born by the Mirror Lake-front property owners is approximately 5 percent.

The Mirror Lake-front property owners enjoy 31 percent of the total project benefits and bear only 5 percent of the local project costs. The increase in the well-being of these property owners appears to come at the expense of the other property owners.

Recreational Benefits

To estimate the recreational benefits the model presented earlier will be employed plus the water quality conditions information as represented by the LCI in Table 7.

Table 16--Annual Recreation Benefits at Shadow Lake Based on 40,132 Visits

Year a/	With Project			Without Project			Total Benefits	
	Changes in Consumer Surplus	Discounted at		Changes in Consumer Surplus	Discounted at		Discounted at b/	
		7-1/8%	15%		7-1/8%	15%	7-1/8%	15%
1977	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
1978	0	0	0	0	0	0	0	0
1979*	10,044	8,752	7,594	0	0	0	8,752	7,595
1980*	21,612	17,580	14,210	0	0	0	17,580	14,210
1981*	35,147	26,688	20,095	0	0	0	26,689	20,095
1982*	51,230	36,313	25,470	0	0	0	36,314	25,470
1983	51,230	33,898	22,148	0	0	0	33,898	22,148
1984	51,230	31,643	19,259	0	0	0	31,644	19,259
1985	51,230	29,539	16,747	0	0	0	29,539	16,747
1986	51,230	27,574	14,562	0	0	0	27,574	14,563
1987	51,230	25,740	12,663	0	0	0	25,740	12,663
1988	51,230	24,028	11,011	0	0	0	24,028	11,011
1989	51,230	22,430	9,575	0	0	0	22,430	9,575
1990	51,230	20,938	8,326	0	0	0	20,938	8,326
1991	51,230	19,545	7,240	0	0	0	19,546	7,240
1992	51,230	18,245	6,295	0	0	0	18,246	9,296
1993	51,230	17,032	5,474	0	0	0	17,032	5,475
1994	51,230	15,899	4,760	0	0	0	15,899	4,761
1995	51,230	14,841	4,139	0	0	0	14,842	4,140
1996	51,230	13,854	3,599	0	0	0	13,855	3,600
1997	51,230	12,933	3,130	0	0	0	12,933	3,130
1998	51,230	12,073	2,721	0	0	0	12,073	2,722
1999*	51,230	11,270	2,366	16,557	3,642	765	15,715	3,131
2000*	51,230	10,520	2,058	29,800	6,121	1,198	16,641	3,256
2001*	51,230	9,820	1,789	40,881	7,836	1,427	17,656	3,216
2002*	51,230	9,168	1,556	50,393	4,018	1,532	18,186	3,088
2003	51,230	8,557	1,353	50,393	8,417	1,330	16,974	2,683
2004	51,230	7,988	1,176	50,393	7,857	1,154	15,845	2,335
2005	51,230	7,457	1,023	50,393	7,335	1,008	14,192	2,031
2006	51,230	6,961	889	50,393	6,847	877	13,808	1,766
2007	51,230	6,498	773	50,393	6,391	761	12,889	1,534
2008	51,230	6,066	672	50,393	5,967	660	12,033	1,332
2009*	51,230	5,662	585	53,433	5,905	609	11,567	1,194
2010*	51,230	5,286	508	58,734	6,060	581	11,346	1,089
2011	51,230	4,934	442	58,734	5,657	505	10,591	947
2012	51,230	4,606	384	58,734	5,281	441	9,887	825
2013	51,230	4,300	334	58,734	4,930	382	9,230	716
2014	51,230	4,014	290	58,734	4,602	335	8,616	625
2015	51,230	3,746	252	58,734	4,295	288	8,041	540
2016	51,230	3,498	219	58,734	4,011	253	7,509	472
2017	51,230	3,265	191	58,734	3,743	217	7,008	408
2018	51,230	3,048	166	58,734	3,494	188	6,542	354
2019	51,230	2,845	145	58,734	3,262	164	6,107	309
2020	51,230	2,655	126	58,734	3,044	147	5,699	273
2021	51,230	2.479	109	58,734	2.842	123	5,321	232
2022	51,230	2,314	95	58,734	2,653	112	4.967	207
2023	51,230	2,160	83	58,734	2,476	94	4,636	177
2024	51,230	2,017	72	58,734	2,312	82	4,329	154
2025	51,230	1,882	63	58,734	2,158	70	4,040	133
2026	51,230	1,757	54	58,734	2,014	65	3,771	119
	Total:	$574,335	236,810	Total:	138,170	15,373	713,298	252,172

a/Years in which water quality changes occur are denoted by an asterisk.
b/Total benefits are equal to the sum of the with project benefits and the without project benefits (costs avoided).

Table 17--Annual Recreation Benefits at Shadow Lake Based on 76,026 Visits

Year a/	With Project			Without Project			Total Benefits	
	Changes in Consumer Surplus	Discounted at		Changes in Consumer Surplus	Discounted at		Discounted at b/	
		7-1/8%	15%		7-1/8%	15%	7-1/8%	15%
1977	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
1978	0	0	0	0	0	0	0	0
1979*	19,027	16,580	14,387	0	0	0	16,580	14,387
1980*	40,942	33,304	26,920	0	0	0	33,304	26,920
1981*	66,584	50,559	38,069	0	0	0	50,560	38,070
1982*	97,053	68,794	48,252	0	0	0	68,795	48,253
1983	97,053	64,219	41,958	0	0	0	64,219	41,959
1984	97,053	59,947	36,485	0	0	0	59,948	36,486
1985	97,053	55,960	31,726	0	0	0	55,961	31,727
1986	97,053	52,238	27,588	0	0	0	52,239	27,589
1987	97,053	48,764	23,990	0	0	0	48,764	23,990
1988	97,053	45,520	20,860	0	0	0	45,521	20,861
1989	97,053	42,493	18,139	0	0	0	42,493	18,140
1990	97,053	39,666	15,773	0	0	0	39,667	15,774
1991	97,053	37,028	13,716	0	0	0	37,029	13,716
1992	97,053	34,565	11,927	0	0	0	34,566	11,927
1993	97,053	32,266	10,371	0	0	0	32,267	10,372
1994	97,053	30,120	9,018	0	0	0	30,121	9.019
1995	97,053	28,117	7,842	0	0	0	28,117	7,842
1996	97,053	26,247	6,819	0	0	0	26,247	6,819
1997	97,053	24,501	5,929	0	0	0	24,501	5,930
1998	97,053	22,871	5,156	0	0	0	22,872	5,156
1999*	97,053	21,350	4,483	31,365	6,900	1,449	28,250	5,932
2000*	97,053	19,930	3,399	56,468	11,596	2,269	31,577	6,168
2001*	97,053	18,604	3,390	77,445	14,846	2,705	33,450	6.095
2002*	97,053	17,367	2,948	95,465	17,083	2,900	34,451	5,848
2003	97,053	16,212	2,563	95,465	15,947	2,522	32,159	5,086
2004	97.053	15,134	2,229	95,465	14,886	2,193	30,020	4,422
2005	97,053	14,127	1,938	95,465	13,896	1,907	28,024	3,846
2006	97,053	13,187	1,685	95,465	12,922	1,658	26,160	3,344
2007	97,053	12,310	1,465	95,465	12,109	1,442	24,420	2,908
2008	97,053	11,491	1,274	95,465	11,303	1,253	22,795	2,528
2009*	97,053	10,727	1,108	101,224	11,118	1,156	21,946	2,264
2010*	97,053	10.014	963	111,263	11,480	1,105	21,494	2,069
2011	97,053	9,348	838	111,263	10,717	961	20,065	1,799
2012	97,053	8,726	729	111,263	10,004	835	18,730	1,564
2013	97,053	8,146	633	111,263	9,338	726	17,485	1,360
2014	97,053	7,604	551	111,263	8,717	632	16,321	1,183
2015	97,053	7,098	479	111,263	8,138	549	15,235	1,028
2016	97,053	6,626	417	111,263	7,596	477	14,222	895
2017	97,053	6,186	362	111,263	7,091	415	13,277	777
2018	97,053	5,774	315	111,263	6,620	361	12,394	676
2019	97,053	5,390	273	111,263	6,179	314	11,569	588
2020	97,053	5,032	238	111,263	5,768	273	10,800	511
2021	97,053	4,697	207	111,263	5,385	239	10,082	444
2022	97,053	4,385	180	111,263	5,026	207	9,411	387
2023	97,053	4,093	157	111,263	4,692	180	8,795	337
2024	97,053	3,821	136	111,263	4,380	156	8,201	292
2025	97,053	3,567	118	111,263	4,088	136	7,656	254
2026	97,053	3,329	103	111,263	3,817	118	7,146	221
	Total:	$1,088,050	$448,625	Total:	$261,768	$29,128	$1,349,818	$ 477,764

a/Years in which water quality changes occur are denoted by an asterisk.
b/Total benefits are equal to the sum of the with project benefits and the without project benefits (costs avoided).

expected annual usage of Shadow Lake during each year of the project will probably vary between the two reported extremes, and assuming the social rate of discount most likely falls within the two discount rates used, the reported benefit figures represent the best possible confidence region attainable for recreational benefits.

The purpose of determining recreation benefits was twofold: (1) to estimate the benefits accruing to nonlocal recreators which would then be added to property value benefits and thereby completing the estimation of total project benefits; and (2) to allow examination of the hypothesis that property value impacts and recreation benefits should be similar in magnitude given the assumption that the former is comprised primarily of the latter.

With respect to the first issue the nonlocal recreation benefits, based on a 15 percent non-local usage rate, are estimated as follows: \$106,995 and \$37,825 when based on 40,132 users and discounted at 7-1/8 and 15 percent, respectively; and \$202,472 and \$71,665 when based on 76,026 users and discounted at 7-1/8 and 15 percent, respectively. Assuming that the range of recreators will reflect an average of the extremes one might expect the nonlocal recreation benefits to fall between \$154,734 or \$54,745, depending on the discount rate used.

When discounted at 7-1/8 percent, total property value impacts were estimated to be \$225,923 at Mirror Lake and \$819,877 at Shadow Lake. Because of limited public access to Mirror Lake, recreation benefits were estimated only for Shadow Lake; consequently, only the latter figure of \$819,877 in property value changes will be used for comparison purposes. As indicated, total recreational benefits range, depending on usage rate, from \$713,172 to \$1,349,818 with a 7-1/8 percent discount rate. Adjusting

to exclude the assumed 15 percent nonlocal usage, and again assuming the average of the extreme usage rates, the probably average is $876,770. When compared with the estimate of discounted property value impacts of $819,877 a minimal difference is revealed.[11/] This is of particular interest given that the estimation procedures are so different. Consequently, this tends to lend credence to the estimation, as one method reinforces the level of acceptability of the other.

Project Efficiency

The efficiency issue examines whether the reallocation of resources to the project, e.g., those used for water pollution control, provide benefits in excess of the value of the resources used. Ideally, one would wish to determine not only if the resources had been optimally allocated among alternative users, but also whether they are optimally allocated for a given project. This study does not provide an analysis that compares the flow of benefits of this project with possible alternative projects, or the determination of the optimal project scale. The analysis is restricted to an evaluation of a project that had been sanctioned by the political process which likely did not compare it economically with alternative projects. The absence of the necessary cost functions prohibit the determination of optimal project size.

One common approach for examining project efficiency is to express the impact in term of benefit-cost ratios. If the ratio is greater than one, the present value of discounted project benefits exceeds that of discounted project costs and the project has met at least a minimum standard of economic efficiency.

11/For comparison purposes only the benefits discounted at 7-1/8 percent are used.

The total project benefits are equal to the property value impacts plus the benefits accruing to the non-local recreators. Total property value impacts are $1,045,800 and $821,147 when discounted at 7-1/8 and 15 percent, respectively. The reader is reminded that property value benefits may be somewhat overstated to the extent that Mirror Lake property owners might not fully value the benefit flow from the enhancement of Shadow Lake because of the more accessible substitute they have in Mirror Lake. Total non-local recreation benefits associated with the average use rates are $154,734 and $54,745. Consequently, total project benefits are $1,200,534 and $875,892 for the 7-1/8 and 15 percent discount rates, respectively. Given the corresponding cost figures of $439,872 and $469,650 favorable ratios of benefits to costs are provided regardless of the discount rate used, i.e., 2.73 and 1.86. Therefore, it may be concluded from the foregoing analysis that the decision to undertake the lake rehabilitation project at Mirror and Shadow Lakes was an efficient one.

CASE STUDY II - WHITE CLAY LAKE

White Clay Lake is a 100 ha, natural lake in Shawano County in northeastern Wisconsin. The township had a 1980 population of 1200. Second homes and the recreation industry provided a major part of the local economy. Shawano Lake is the central recreational attraction of the county. White Clay Lake is primarily used for quiet fishing as an alternative to large, noisy motors on Shawano Lake. It is also used extensively for ice fishing.

Watershed Characteristics

The lake is in a small watershed of 1200 ha that is dominated by agriculture. Sixty-six percent of the land is cropped. There are twenty livestock concentrations in the watershed and another five which potentially affect the watershed through manure spreading. Woodlands and wetlands, one small resort, a crossroads bar, a church, and a few non-farm residences comprise the rest of the watershed. Thus, most pollutants entering the lake probably originate from agricultural activities.

Agriculture in the White Clay Lake watershed is primarily dairying. The trend on these dairy farms has been towards larger herds concentrated in exercise yards and feedlots. Associated with this has been more land devoted to corn production and potentially more sediment and nutrient runoff and a hastening of the lake eutrophication process. Although White Clay Lake is considered to be of good quality, the phosphorus input to the lake is greater than the concentration level considered dangerous by Vollenweider (49) from the standpoint of eutrophication control (55).

Consequently, this recreational resource became a candidate for lake protection efforts.

Project Chronology

1969 The White Clay Lake watershed was selected for study to measure the significance of agricultural pollution but funding was not available.

1971 Shawano County Agricultural Stabilization and Conservation Committee and the Soil Conservation Service began providing intensified assistance to watershed farmers. Special funds were set aside through the Rural Environmental Assistance Program (REAP). Three animal waste projects and one seeding project were cost shared with $8,727.

1972 Shawano County Soil and Water Conservation District supervisors accepted the White Clay Lake project as a Lumberjack Resource Conservation and Development project and requested a complete soil survey on the 1200 ha White Clay Lake watershed. REAP provided an additional $7,098 for three animal waste projects and one sediment retention and water control structure.

1973 Intensive monitoring by the University of Wisconsin Extension began in the White Clay Lake watershed. Funding was provided by the Upper Great Lakes Regional Commission. The study documented the movement of nutrients and sediment from agricultural land, barnyards, and animal rest areas into the lake.

1974 REAP provided $6,000 for another animal waste project and a waterway project.

1975 The White Clay Lake District was formed by the Town of Washington, Shawano County. The district submitted a technical assistance application to DNR. No feasibility study was required by DNR because of the previous monitoring.

A lake management and protection plan for White Clay Lake was developed by local residents with assistance from the Soil Conservation Service and University of Wisconsin Extension. It was presented to the lake district in May. The district approved the plan and immediately applied for financial assistance from DNR and EPA. A hearing on the application was held by DNR in June.

1976 EPA made its first award under the Federal Clean Lakes Program, White Clay Lake was the only project with work confined to watershed management. DNR funds had been approved earlier. By fall, construction had begun on land management practices and manure storage facilities.

1977-1978 Work continued on barnyard improvements such as manure storage facilities, improved feeding and exercise areas, gutters and downspouts on buildings, and diversion ditches to prevent as much water as possible from moving through the barnyard. Land management practices included streambank stabilization, animal crossings, and grassed waterways underlain by tile.

1979 The project was completed at a cost of approximately $250,000.

1977-1982 Grants from the EPA to the University of Wisconsin Extension provided for an evaluation of the limnological, social and economic impacts of the project.

Lake Stabilization Project

In contrast to Mirror Lake in Waupaca, a stabilization effort was required at White Clay Lake in order to maintain the already high level of water quality. The plan was based on the design and use of conservation practices which would reduce nutrient and sediment movement into waterways. As agriculture (dairying) is the dominant activity in the watershed, handling of animal waste was the major problem. Conservation practices include manure storage facilities, improved feeding and exercise areas, gutters and downspouts on buildings, and diversion ditches to prevent water from moving through the barnyard.

Coupled with the animal waste handling phase of the project is the installation of land control measures to reduce the movement of sediments and nutrients to the lake. These measures include fences to protect streambank and lakeshore areas, animal crossings where needed, alternative animal watering facilities, construction of diversion ditches, grass waterways, and installation of tile. Total project cost was $214,000.

Manure Storage and Barnyard Improvements

Livestock wastes were identified as a major potential source of pollutants in the White Clay Lake Management Plan. The plan described three types of needed control practices: (1) manure storage; (2) feed and rest area waste control; and (3) clearwater collection and diversion around barnyards. The White Clay Lake Management Plan asked for a total of $149,000 to be used in improving animal waste management practices. It was soon apparent that this amount was not enough to fund the desired animal waste management practices. The total amount of $183,380 was provided by EPA and DNR to the lake district and was used for animal waste control. The originally proposed land management practices were to be funded by the more traditional County Agricultural Stabilization and Conservation Service (ASCS) cost sharing as it became available. A supplementary grant of $79,313 was received in 1979 from DNR and EPA to complete livestock waste management practices. ASCS REAP cost-sharing funded animal waste facilities at six watershed barnyards to a total amount of $16,390.

As a result of combined cost sharing dollars from three agencies (EPA, DNR, ASCS) and technical help from SCS and UW Extension, a total of 19 of the 25 farms which have the potential to impact White Clay Lake had management practices for manure handling and/or barnyard improvement installed by 1981. Eighteen of these have manure storage capabilities. Barnyard improvements, clearwater diversion and/or settling filter areas have been installed at 18 of the livestock concentration areas. Fourteen barnyards had feedlot improvements, twelve had clearwater diversions installed, and fifteen had settling filter areas installed. For more details on manure storage and other barnyard work, see Table 18.

Table 18--Design Specifications, Barnyard Runoff Controls and Manure Storage Facilities, White Clay Lake

Farm Number	Cost Share Source	Manure Storage		Storage Capacity (Cu.Ft.)	Design Animal Units	Design Storage Period (Days)	Other Barnyard Work				Type Barn
		Storage Type	Handling Method				Feedlot Improvement	Clear-water Diversion	Holding Pond	Settling Filter Area	
1	REAP						yes		yes	yes	S
	ILR	CP	P	128,968	120 DC	365					
2	ILR	CP	Sc	19,350	60 H	365					FS
3	ILR	CP+D	P	49,400	80 DC	240	yes	yes		yes	S
					12 C						
4	ILR	P+P	Sc	11,250	60 H	180	yes	yes		yes	L
5	ILR	P+P	Sc	25,350	70 H	360		yes		yes	FS
6	REAP	P+P	Sc	13,500	75 AU			yes		yes	S+L
	ILR	P+P	Sc	19,150	80 DC	180	yes				
					8 C						
7	ILR	CP	St	20,956	43 AU	180				yes	S
8	ILR	CP	P	99,700	60 DC	365	yes	yes		yes	S+FS
					60 H						
					25 C						
					50 B						
9	ILR	CP	St	53,353	60 AU	240	yes	yes		yes	S
10	REAP	P+P	L	9,870							S
	ILR				45 H		yes	yes		yes	
11	ILR	CP	St	34,020	70 AU	180	yes	yes		yes	S+L
12	ILR*	P+P	Sc	6,000*	35 S		yes	yes		yes	
					315 FP						
13	ILR*	P+P	St	28,800	38 C	270	yes			yes	S
					22 H						
14	ILR*	P+P	St	34,400*	30 DC	365				yes	S
					20 H						
15	ILR*	P+P		5,100*	35 H	180	yes			yes	S
16	REAP	P+P	Sc	23,400	52 AU	180		yes		yes	S
	ILR*						yes*			yes	
17	ACP	CP		41,260	64 AU	180	yes	yes			S
18	ILR						yes	yes	yes		S
19	REAP	CP	St	48,000	100C	120					F
	?	SS	P	47,000	200C						

Abreviations Used:

Cost Share Source

REAP - ASCS REAP cost sharing
ILR - Inland Lakes Renewal (EPA/DNR)
ACP - ASCS ACP cost sharing

Storage Type

CP - concrete pit
D - dike
P+P - post and plank

Design Animal Units

DC - dairy cows
H - heifers
C - calves
B - beef cattle
S - sows
FP - feeder pigs
AU - unspecified animal units

Handling Method

P - pump
Sc - scraper
St - stacker
L - loader

Barn Type

S - stanchion
FS - free stall
L - loose

* These projects funded by 1979 EPA Grant

Source: (31).

Total cost of the EPA-DNR funded animal waste management project was $292,567 with $143,200 and $119,493 covered by EPA and State cost-sharing, respectively. Total eligible improvement costs ranged from $4,426 to $43,544 and averaged $17,210. Detailed information on cost of work completed at each barnyard is contained in Table 19. Farmers paid at least 10 percent of the cost of the improvement projects, and as high as 34 percent when ineligible costs of stackers are considered.

Because construction of manure storage facilities and other barnyard control practices generally was done at the same time, it is not possible to determine separate costs of the practices installed. It can be seen that concrete costs were highest--representing approximately 70 percent of the total project cost. Excavation and construction costs averaged 15 percent of the total eligible cost. Pumps and stackers were also significant for those manure storage facilities which required them.

Watershed Land Management Improvements

The White Clay Lake Management Plan also identified the need for land management practices to control nutrient and sediment transport from cropland. Prior to the EPA-DNR Inland Lake ASCS funded several land management practices including a grass waterway and sediment control project which formed a one-acre pond. A total of $3,932 was spent on these projects.

Initially the White Clay Lake Management Plan requested $64,500 for land treatments. This included $6,500 to protect streambank and lakeshore areas, and to construct animal crossings and animal watering facilities where needed. An additional $55,000 was requested to construct diversion ditches, grass waterways and installation of tile where it was needed with these ditches and waterways to reduce erosion.

Table 19 --Project Costs, Barnyard Runoff Controls and Manure Storage Facilities, White Clay Lake

Farm Number/ Program	Original Estimated Cost (Dollars)	Eligible Costs	Breakdown of Total Costs (Dollars)				
			Excavation and Construction	Pump (P) Stacker (S) or other (O)	Fencing, Lumber, Misc.	Concrete	Farmer's Time and Materials
1 REAP		~2,500 a/					
ILR	19,500	28,196	5306	6195 (P)	~207	16,103	385
2 ILR	7,100	9,516	1412		~169	7,650	285
3 ILR	26,200	35,790	3986	6893 (P)	1027	22,949	935
4 ILR	9,000	11,516	1840		~66	9,228	382
5 ILR	8,500	9,878	944			8,874	60
6 REAP		~2,500 a/					
ILR	13,203	14,849	2015		~3871	8,480	483
7 ILR	10,000	11,935	1166	3203 (S) b/	138	9,901	730
8 ILR	29,712	43,544	6210	6600 (P)	~1579	28,760	395
9 ILR		26,133	2460	2358 (S) b/	2346	21,180	147
10 ILR	7,600	8,330	1172		408	6,645	105
11 ILR		14,755	1802	2358 (S) b/	105	12,630	218
12 ILR	9,008	9,470	3066			6,134	270
13 ILR	15,872	19,784	1734	2450 (O) b/	5675	12,302	73
14 ILR	9,345	10,209	2081	3650 (S) b/	698	7,430	135
15 ILR	5,898	44,026	757			3,354	
16 REAP		~2,500 a/					
ILR	5,998	7,642	778		1443	5,301	120
17 ACP		~2,500 a/					
18 ILR	18,025	26,588	6731	4900 (P,O) b/	447	16,460	350
19		~2,500 a/					

a/Maximum allowed ASCS cost-share portion.
b/All or a portion of these costs were not eligible for cost sharing.
Source: (30).

Another $3,000 for streambank stabilization was also requested. However, between 1976 and 1980 only $8,263 was available from ASCS cost sharing.

Land management practices completed at White Clay Lake include several sod grass waterways, underlain with tile, fencing of a portion of the lake,a field diversion system, and a terrace on a steeper portion of the watershed. Two shallow wildlife ponds were also built with ASCS funds.

Since future dollars available to the White Clay Lake area must be divided among all conservation needs in the county, it is likely to be a long time before all the initially envisioned land treatment projects can be carried out.

There are several important land management practices that can be pursued without cost sharing. One of these is selection of crop rotations or a conservation cropping system appropriate to the soil and slope of each given field. By selecting a rotation with more years of hay than corn, soil loss can be reduced. Several of the farmers in the watershed have long-term cooperator agreements with SCS which include conservation cropping systems.

Finally, protection of the lake's water quality requires anticipation of land use changes that may jeopardize water quality. Much of the shoreland of the lake is in wetlands which appear to buffer the lake from the full impacts of nutrient and sediment loadings (17). There are also soils which are severely limited for onsite waste disposal. The White Clay Lake District choice to request that these lands be put into a ON-1 Natural Resources Preservation First Class zoning category that would protect the wetlands and lake from more development. Thus, long

range protection of the lake's critical buffer area was ensured. The White Clay Lake shoreland was the first area in Shawano County to have this zoning classification.

Project Evaluation

An extensive monitoring and modeling effort was undertaken in the White Clay Lake watershed to evaluate the effectiveness of installed non-point source control practices. Included in this effort was monitoring of three subwatersheds shown on Map 2 to determine sediment and nutrient loadings (32,33), an analysis of the lakes groundwater regime (44), lake water quality monitoring (32, 33), an analysis of the effect of wetlands on sediment and nutrient delivery (17), determination of long-term sediment movement based on Cesium-137 movement (26), and an analysis of phosphorus movement in fields due to precipitation (54). A hydrologic and nutrient budget on the lake has been developed. In addition to the monitoring studies, detailed climatological information and land use data including cropping and livestock waste handling practices was collected between 1974 and 1979. Several models have been used to examine the relationship between changes in land management practices, climatic factors, and monitored sediment and nutrient loadings (30,31). A discussion of selected aspects of several of these studies follows.

Watershed Monitoring Results

Flow monitoring devices were installed to isolate three watersheds--the south watershed of about 195 hectares, the east watershed of 328 hectares, and the Manthei watershed of 22.5 hectares (Map 2). The larger two watersheds were selected to be representative of the soil, topography, and land use of the rest of the watershed as well as other areas

Map 2
WHITE CLAY LAKE
WATERSHED
FIELD DELINEATIONS
FIELD BOUNDARIES
WATERSHED BOUNDARY
SUBWATERSHED BOUNDARIE
STREAM CHANNEL OR
WATERWAY
WHITE CLAY LAKE
MANTHEI
SUBWATERSHED
EAST BRANCH
SUBWATERSHED
SOUTH BRANCH
SUBWATERSHED

of northeastern Wisconsin. A monitoring station on the lake's outlet stream measures output of surface water from the entire watershed. Water samples taken weekly and during runoff events at each station are analyzed for residue, phosphorus, nitrogen, and chloride content.

A survey of groundwater movement and quality in the basin complemented the hydrologic and nutrient transport studies for the lake. Observations on a network of wells and seepage collectors were used to estimate rates of water movement into the lake. Water level recorders showed the relationship between lake level and water table fluctuations. Samples from observation wells were analyzed for chloride, nitrogen, and phosphorus content. Samples from private water supplies were analyzed to determine the water quality of the deeper aquifer. Groundwater monitoring is continued on a quarterly basis.

Project weather stations within the watershed provide a continuous measurement of precipitation, temperature, and relative humidity. Maximum and minimum temperature readings are recorded weekly. Frost depth is monitored using fluorescein tubes at several places in the watershed from December through April (14).

A summary of the water, residue, phosphorus and nitrogen transport from the East Branch and South Branch subwatersheds for the period 1974-1979 is presented in Table 20. The variability in this monitoring data is apparent: water volume varies from the annual total of 138,825 m^3 to 1,209,815 m^3 in the East Branch. Other parameters vary in a similar manner. Observed climatic events provide some explanation. These events include heavy snowfalls in the winter of 1975-1976, a dry growing season in 1976 and subsequent dry year in 1977, and abundant snowfall in the winter of 1978-1979. Shown in Table 21 are total annual rainfall and

Table 20.--Summary of Water, Phosphorus, Nitrogen, and Residue Transport

	1974	1975	1976	1977	1978	1979
East Branch						
Water volume (m^3)	405,000	616,000	682,000	138,825	238,096	1,209,815
Total phosphorus (kg)	214.6	166.9	703	85.3	50.8	293.2
Average concentration (mg/m^3)	.53	.27	1.03	.625	.213	.241
Range of concentration (mg/m^3)	(.02-6.1)	(.01-3.47)	(.01-7.85)	(.01-3.65)	(.02-5.75)	(.02-1.45)
Total nitrogen (kg)	1,660	2,221	2,552	785	1,666	5,984
Average concentration (mg/m^3)	4.10	3.61	3.74	5.65	7.00	4.94
Range of concentration (mg/m^3)	(1.8-15.5)	(1.55-26.8)	(1.57-8.18)	(1.51-16.30)	(2.60-18.30)	(1.47-8.34)
Residue (kg)	227,400	184,000	197,300	82,420	143,273	587,934
Average concentration (mg/m^3)	563	299	289	594	602	405
Range of concentration (mg/m^3)	(10-6210)	(60-164)	(29-827)	(287-1100)	(180-1030)	(257-1270)
South Branch						
Water volume (m^3)	292,000	359,000	194,000	20,438	196,058	820,790
Total phosphorus (kg)	109.00	161.60	72.10	4.05	23.20	105.40
Average concentration (mg/m^3)	.360	.450	.370	.199	.118	.128
Range of concentration (mg/m^3)	(.05-7.00)	(.01-2.93)	(.01-6.42)	(.01-4.15)	(<.01-2.77)	(.02-.60)
Total nitrogen (kg)	1,323	1,980	950	86	1,290	6,220
Average concentration (mg/m^3)	4.53	5.53	4.91	4.23	6.58	7.58
Range of concentration (mg/m^3)	(1.40-8.20)	(.55-18.80)	(1.32-12.50)	(.97-9.04)	(.32-16.20)	(.60-23.70)
Residue (kg)	145,400	125,700	78,940	8,845	101,615	453,493
Average concentration (mg/m^3)	498	350	408	433	518	552
Range of concentration (mg/m^3)	(10-6000)	(50-4100)	(250-727)	(201-755)	(88-963)	(334-814)

Source: (33); 1979 information provided by James O. Peterson, Associate Professor, University of Wisconsin-Madison.

Table 21--Fluctuations in Climatic Factors Affecting White Clay Lake

	1974	1975	1976	1977	1978	1979
Annual rainfall (inches)	22.55	23.36	21.09	21.20	29.54	35.13
Storm rainfall erosion index	90.00	73.80	20.80	16.90	135.00	183.00[a/]
Thaw rainfall erosion index	5.10	5.60	17.60	9.00	4.90	7.50
Annual rainfall erosion index	95.10	79.40	38.40	25.90	139.90	190.50[a/]

a/ Includes an estimated value of 20 for one two-inch rainfall

Source: (30)

rainfall erosion indices calculated to give some indication of the variability in climatic conditions during the period of study.

Eleven of the seventeen EPA-DNR livestock waste control facilities were completed in the fall of 1976 and summer of 1977 and the rest were completed during 1979. The amount and intensity of rainfall during 1979 tended to mask any reductions in phosphorus loading that would be attributable to the installation of all control practices. However, a comparison of average total phosphorus loading in the East Branch from 1974 to 1976 and 1977 to 1979 as shown in Table 22 indiates that while total rainfall and rainfall intensity averaged 128 percent and 167 percent of the earlier period, total phosphorus loading was only 39 percent of the earlier period. Thus, it appeared that the livestock and land management practices installed at White Clay Lake did help to reduce total phosphorus loading to the lake.

Lake water quality monitoring included monthly measurements of dissolved oxygen and temperature profiles, Secchi depth and laboratory analysis of water samples from the inlet, lake surface, and at 6-meter and 12-meter depths within the lake. Analyses were made for nitrate, nitrite, ammonium-N, organic nitrogen, reactive phosphorus, total phosphorus, calcium, magnesium, sodium, potassium, chloride, sulfate, alkalinity, and pH.

Part of the limnological analysis included examining the effects of littoral marshland on lake water quality. Protection of littoral zones is thought to be a critical factor in maintaining high quality of lake water. The objectives of the marsh study were to evaluate changes in surface water quality discharged from the subwatershed as it flows through the wetland and to evaluate the ability of wetland macrophytes

Table 22--Average Annual East Branch and White Clay Lake Loading and Climatic Conditions

	1974-76	1977-79
Annual flow (m^3)	566,667	528,912
Total phosphorus loading (kg)	361.5	142.0
Annual rainfall (cm)	22.3	28.6
Rainfall erosion index	71.0	118.8

Source: (30).

to remove nutrient and sediment loads from the surface water discharge.

Estimated Reductions in Phosphorus Loading Attributable to Livestock Waste Management Controls

Reduction in total phosphorus loading attributable to changes in livestock waste management practices were estimated using a method initially developed by Robinson and Draper (36) and later modified by Moore and Madison (29), and Moore (28) for Wisconsin. This method estimates loadings from winter-spread manure, barnyards and above ground manure storage facilities. The method provides a means of removing climatic variability from the evaluation of phosphorus reduction attributable to livestock waste practices.

Livestock numbers were determined for the years 1970, 1974 and 1978 from township tax assessor records, and farmer interviews. This information was converted into animal units (AU) assuming a milk cow equaled 1.3 AU, heifers are .8 AU, calves .25 AU, sows and gilts .25 AU and feeder pigs .05 AU. Total animal units were 1,545, 1,844 and 1,960 in 1970, 1974 and 1978, respectively.

Total phosphorus and manure production were calculated for:(1) 1970 prior to any barnyard improvement; (2) 1974 when REAP funded installation had been completed; (3) 1978 when the initial Inland Lake Protection and Renewal (ILR) funded work had been installed; and (4) the future when the additional ILR funded projects will have been completed. This calculation was based on an assumed 5 month winter period for Shawano County. Thus 5 months "manure storage capacity" for each farm is necessary to avoid winter spreading. The known manure storage capacity of each farm was then subtracted from the total calculated winter production

for each year of interest. This difference (the calculated manure actually spread on fields) was assumed to be equal to the total manure actually spread in the winter by each farmer associated with the White Clay Lake watershed. The proportion of this total manure spread inside the White Clay Lake watershed boundaries was assumed to be proportional to the percentage of cropland each farmer worked within the watershed. The total phosphorus associated with this produced and spread manure was calculated using 0.033 kg and 0.068 kg per animal unit per day of dairy stock and swine, respectively.

Based on Moore, total -P runoff from winter spread manure was assumed to be 8 percent of that in the manure (28). A critical distance of 40 meters from a stream or waterway and average attenuation rate of 50 percent for winter spread manure within that critical distance was assumed.

As seen in Table 23, this analysis showed that while potentially deliverable total phosphorus associated with winter spread manure increased from 66.7 kg to 84.1 kg from 1970 to 1980, estimated delivery decreased from 66.7 kg to 25.9 kg.

Based on Moore, total -P runoff from barnyards was assumed to be 4 percent of the total P in manure produced annually (28). Critical distance and attenuation was similar to winter spread manure. No research was available to indicate what reduction in total -P runoff from treated barnyards would be. An assumption of 50 percent reduction in P runoff was used. Barnyard controls were estimated to reduce associated phosphorus loading from 339.6 kg to 223.8 kg in the entire watershed, and from 64.4 kg to 31.9 kg in the East Branch subwatershed. The total estimated reduction in barnyard runoff was 46 percent.

Table 23--Average Annual Total Phosphorus Loadings from Animal Waste

	A. EAST BRANCH WATERSHED				B. WHITE CLAY LAKE WATERSHED			
	Period I (1970 and before)		Period II (1971-1974)		Period III (1975-1978)		Period IV (1979 and future)	
Runoff Source[a]	Potentially Deliverable	With Controls	Potentially Deliverable	With Controls	Potentially Deliverable	With Controls	Potentially Deliverable	With Controls
EAST BRANCH SUBWATERSHED								
Barnyards	64.4	64.4	60	60.7	55.3	36.8	55.3	31.9
Winter Spread Manure	24.2	24.2	25	23.4	27.0	8.4	29.0	2.6
Above Ground Storage	-	-	-	-	-	1.2	-	4.7
TOTAL RUNOFF	88.6	88.6	86.0	84.1	84.3	46.4	84.3	34.5
Percent of potentially deliverable Total P	-	100	-	98	-	55	-	40
Percent of Period I loading	100	100	97	95	95	52	95	39
WHITE CLAY LAKE WATERSHED								
Barnyards	339.6	339.6	371.3	336.8	398.0	362.4	398.0	223.8
Winter Spread Manure	66.7	66.7	76.0	72.9	84.1	35.6	84.1	25.9
Above Ground Storage	-	-	-	-	-	9.7	-	13.0
TOTAL RUNOFF	406.3	406.3	447.8	409.7	482.1	307.7	482.1	262.7
Percent of potentially deliverable Total P	-	100	-	91	-	64	-	54
Percent of Period I loading	100	100	110	101	119	76	119	64

[a]Amounts are expressed in kilograms

Source: (30).

There is some total phosphorus loss associated with above-ground solid waste storage facilities. Based on Moore (1979) this was estimated to be 3 percent of the total P produced at the site annually (27). In the entire watershed in 1980 this was estimated to be 13 kg or about one-quarter of the estimated 1980 reduction in total -P runoff from winter spread manure.

Based on the analysis of manure spread, barnyard and above-ground manure storage, in 1970 presumably 100 percent of the potentially deliverable manure-associated phosphorus actually reached White Clay Lake streams. By 1978 and 1980, only 76 percent and 54 percent respectively of the potentially deliverable phosphorus reached White Clay Lake streams. While the amount of potentially deliverable phosphorus increased by 19 percent from 1970 to 1980, the loading was estimated to be reduced by 36 percent. Estimated reductions in the East Branch watershed were even greater.

Total Phosphorus Reduction

Total phosphorus availability is not only influenced by animal waste management, but also control of sediment runoff, natural background sources and septic systems. The reduction in phosphorus by animal waste management has been discussed above. Research has not been completed regarding nutrient contributions from the other potential nutrient sources. However, it is possible to make statements on total phosphorus based upon the preceding discussion on animal waste control and lake water quality monitoring efforts used to calculate the lake nutrient budget.

Critical loadings of phosphorus to lakes of the size of White Clay Lake have been indicated by Vollenweider (49). He indicated .07 g/m^2/year

is a permissible loading rate. Rates higher than .13 g/m^2/year are considered dangerous from the standpoint of eutrophication control. Loadings for total P to White Clay Lake were calculated to be .94, .93, 1.65, and .47 g/m^2/year in 1974, 1975, 1976 and 1977, respectively, based on monitored data and extrapolating it to the rest of the watershed. Percentage soluble P averaged 28, 20, and 40 percent of total P from surface, groundwater, and precipitation inputs, respectively. A very rough estimate of soluble P loading from all inputs would then yield .22, .26, .27, and .47 g/m^2year for 1974, 1975, 1976, and 1977. All these loadings are above those indicated to be critical loading levels if the lake is to remain oligotrophic.

It is apparent that the surface water inputs, averaging 66 percent of the total, are an important component of total and soluble phosphorus loadings to the lake. Reduction in surface water input by half would reduce loading to the lake by a third. Significant reductions in surface water loadings coupled with the continued buffering capability of the wetland, should be adequate to maintain current water quality conditions in the lake, and to prevent an acceleration of eutrophication. Additional discussion of the water quality of White Clay Lake and the level of eutrophication present is found in the following section.

Water Quality of White Clay Lake

Water quality of a lake is an elusive concept to define much less protect. In an effort to describe the water quality of White Clay Lake, measures of various water quality parameters will be provided along with classifications of water quality. In particular, the LCI which will be used in the estimation of recreation benefits.

Macrophyte Plant Communities

Sullivan conducted a detailed survey of macrophyte plant communities found in White Clay Lake (42). Fourteen species of plants were found. The four most common species were *Chara* sp., *Certatophyllum demersum*, *Myriophyllum* sp., and *Potamogeton pectinatus*.

Four major plant communities were delineated. The location of the cattail community was estimated by Sullivan from a 1967 lake survey map. Cattails encompassed 29 percent of the lake basin (42). Another emergent plant community of bulrushes was approximately 18 percent of the lake basin. The major littoral plant communities consisted of *Chara* and *Potamogeton* where the water was up to 2.5 meters deep. In depths of 2.5 to 4.0 meters, dense stands of *Ceratophyllum* and *Myriophyllum* were found.

It is likely that if the lake were completely surrounded by cottages, having 70 percent of the lakebed in littoral, and emergent plants might be considered nuisance conditions for boat access and swimming. Because the value of the marsh fringe for water quality protection is locally recognized and there is only one development on the lake, these plant growths have not been considered nuisances. The plants thus can provide habitat for fish and waterfowl.

Dissolved Oxygen

The dissolved oxygen levels found in a lake are fundamental to the distribution of biota (fish and other organisms) and nutrients in the lake. Fish generally require that 5 mg/l dissolved oxygen be maintained to avoid stressful conditions. In Wisconsin, this requirement has been formalized into a water quality standard (NR 102). The distribution of dissolved oxygen can also affect the availability of inorganic nutrients.

Phosphorus is more soluble in anaerobic conditions than in aerobic conditions. Thus, when phosphorus rich sediments are exposed to anaerobic conditions, more phosphorus becomes part of the water column than when the sediments are exposed to aerobic conditions.

Dissolved oxygen (DO) profile surveys have been made at White Clay Lake at approximately monthly intervals from 1974 to 1978. The DO patterns observed are typical of a somewhat eutrophic dimictic lake. During late winter when the lake is stratified and ice cover prevents surface atmospheric reaeration, oxygen depletion generally occurs in the lower three meters. DO levels under 5 mg/l which start to become stressful to fish are generally found below four meters in late winter. At spring, turnover dissolved oxygen becomes mixed throughout the water column. As summer progresses and the lake restratifies, the DO in the hypolimnion becomes reduced. Finally approximately a month after turnover, total oxygen depletion occurs in the lower meter and by early June extends throughout the lower six to seven meters of the lake. Five mg/l DO is generally found one meter above the area of oxygen depletion. The summer pattern of oxygen depletion has remained fairly constant at White Clay Lake, changing only with the time of spring turnover. Fall turnover, occurring in late September or early October, remixes the dissolved oxygen throughout the water column and starts the cycle again. Critical low DO concentrations have not been observed at White Clay Lake during the period of study.

Total Phosphorus and Nitrogen

Phosphorus and nitrogen are generally recognized as the two most important nutrients limiting phytoplankton growth in lakes. Because

nitrogen is extremely soluble, widely dispersed, and capable of being fixed from atmospheric nitrogen by some blue-green algae, it is not generally considered to be the limiting nutrient in lakes. Phosphorus is generally considered to be limiting, if the concentration of nitrogen to phosphorus is greater than 12 to 1. Comparisons of vernal (spring turnover) concentrations of nitrogen and phosphorus in White Clay Lake (Table 24 indicate that the lake tends to be strongly phosphorus limited. The only exception was in 1977 when the ratio of nitrogen to phosphorus was 11 to 1.

From 1974 through 1978, chemical sampling surveys of the lake's profiles at the deepest hole have been conducted at approximately monthly intervals. Analysis for nitrate, nitrite, ammonia, organic nitrogen, total nitrogen, orthophosphorus, and total phosphorus was performed. While nitrogen is not generally considered limiting, Vollenweider has noted a direct correlation between high sustained productivity of algal populations and average concentrations of inorganic and organic nitrogen (49). These relationships and ranges are indicated in Table 25. White Clay Lake tends to be oligo-mesotrophic to meso-eutrophic by this analysis. Patterns of total nitrogen distribution are variable from one year to the next, generally ranging from 800 to 1200 mg/l in the epilimnion. Higher concentrations are found in the hypolimnion during aerobic conditions. Annual variability should be recognized as being attributable to climatic and biotic differences as well as differences in annual nutrient loading. Tolman's calculation indicated an annual lake nitrogen loading of 5.5 g/m^2 of lake surface at White Clay Lake (44). This appears to be in excess of the 1.0 g/m^2 considered permissible and the 2.0 g/m^2 indicated to be dangerous by Vollenweider as levels of total nitrogen loading.

Table 24 --Vernal Total Nitrogen and Total Phosphorus Concentrations and Ratios for White Clay Lake

	1974	1975	1976	1977	1978
Total P (µg/l)	40	20	15	60	30
Total N (µg/l)	1,141	1,130	1,000	660	1,160
Ratio N:P	29	57	67	11	39

Source (31).

Table 25--General Relationship of Lake Productivity to Average Concentrations of Epilimnetic Nitrogen and Total Phosphorus

General Level of Lake Productivity	Inorganic N (µg/l)	Approximate Average Organic N (µg/l)	Total Phosphorus (µg/l)
Ultra-oligotrophic	<200	<200	<5
Oligo-mesotrophic	200-100	200-100	5-10
Meso-eutrophic	300-650	400-700	10-30
Eutrophic	500-1500	700-1200	30-100
Hypereutrophic	>1500	>1200	>100

Source: (49).

Phosphorus, as the limiting nutrient, is the critical nutrient of interest. The relationship between total phosphorus to lake productivity is indicated in Table 25. When compared to levels found in White Clay Lake, these relations indicate that in most years, White Clay Lake tended to be near the lower end of the eutrophic scale. In 1974, there appeared to be higher levels of phosphorus than other years, especially at the time of winter snowmelt. Annual patterns of total phosphorus distribution in the water column vary considerably. However, high phosphorus levels are generally observed in the summer in the hypolimnion when anaerobic conditions exist.

Vollenweider has also given a general summary of the relationship between total phosphorus loading to a lake and the lake's productivity level (49). Annual total phosphorus loadings to White Clay Lake were .94, .93, 1.65, and .47 g/m^2 for 1974, 1975, 1976, and 1977, respectively, indicating that they are in excess of permissible and dangerous levels. The average loading during this period was 1 g/m^2.

Lake Condition Index

As was the case with Mirror/Shadow Lakes, the data on White Clay Lake was translated into a Lake Classification Index to be used in the economic evaluation which follows below.

White Clay Lake had been classified in Uttormark's original work as a 4 (48). More recent measurements revealed that the penalty points of some of the water quality parameters used in constructing the LCI had shifted, resulting in a new value of 5. Table 26 provides a comparison of Uttormark's measure with five later years.

Table 26 --Classification of White Clay Lake Using the Lake Condition Index

LCI ELEMENTS	Uttormark	1974	1975	1976	1977	1978
Dissolved oxygen conditions	2	4	4	4	4	4
Typical secchi depth (transparency)	2	1	1	1	2	1
History of fish kills	0	0	0	0	0	0
Recreational use impairment	0	0	0	0	0	0
TOTAL	4	5	5	5	6	5

Source: Information provided by James O. Peterson, Associate Professor, University of Wisconsin-Madison.

To provide the basis for the economic analysis, it is necessary to establish what the LCI will be both with and without the project. As shown in Table 27, the water quality index has been estimated to remain at a five with the project, but is anticipated to deteriorate to a sixteen in 50 years without the project. For purposes of the economic analysis, the lake is assumed to deteriorate at a constant rate. It is also assumed that after the last change, the water quality will begin to stabilize, at least for the duration of the analysis period.

Table 27--White Clay Lake LCI With and Without Project [a/]

Year	LCI (with Project)	LCI (without Project)	LCI Difference
1976	5	5	0
1980	5	6	1
1984	5	7	2
1988	5	8	3
1992	5	9	4
1996	5	10	5
2000	5	11	6
2004	5	12	7
2008	5	13	8
2012	5	14	9
2016	5	15	10
2020	5	16	11
2026	5	16	11

a/Long-term change estimated by James Peterson, Associate Professor, Soils Department, University of Wisconsin-Madison. Linear progression of deterioration was assumed.

Economic Impacts

The procedure for estimating project impacts of the White Clay Lake project are somewhat different from those employed for the Mirror and Shadow Lake evaluation. The primary reason for this is due to the agricultural setting. Consequently, a model that simulates the farm enterprise is employed to determine the impact of adopting water quality improvement practices. Changes in farm income due to the adoption of the project will reflect project impacts. Additional impacts will be realized as the water quality improvements in the lake will provide benefits that are not captured in the farm model. Therefore, the recreation model will also be used. Total project impacts is estimated by summing these two elements and, as was the case in the Waupaca analysis, benefit and costs will be calculated according to the period of time over which the project serves a useful purpose or when further discounting will have no appreciable effect. And a sensitivity analysis employing the 7-1/8 and 15 percent discount rate will be used. The with and without format is used in this case study as well.

Recreation Benefits

The White Clay Lake project was directed towards stabilization rather than rehabilitation. The effect of the project is shown in Table 27 where the lake Condition Index with the project remains constant at a level of five. Without the project it was assumed that the water quality would steadily decrease until it stabilized at the low water quality level of sixteen. The user population was estimated to be at approximately 7,500.[12/] These recreators were comprised primarily of fisher persons.

12/Annual user counts for White Clay Lake were provided by user counts taken in the morning and late afternoon-evening and then summing the two.

The recreation benefits were estimated using this information and employing the evaluation technique described above. The results are presented in Table 28. The change in consumer surplus reflects the sum of the benefits attributable to the increase in water quality due to the project and the negative benefits that would occur in the absence of the project because of a decline in water quality. As was the practice in the preceeding chapter these changes in consumer surplus are discounted at both 7-1/8 and 15 percent, yielding $80,593 and $24,091, respectively.

Farm Income

There are two reasons to hypothesize an increase in farm income resulting from the adoption of one of the alternative manure storage facilities. First, all of the alternative manure storage techniques result in more nutrients being incorporated into the soil thereby improving soil quality and decreasing purchases of commerical fertilizer. Second, many of these management systems require fewer labor and machinery hours to handle a given quantity of manure than does the daily spreading of manure. This hypothesis was supported by the results of the model. The impact on farm income resulting from the White Clay Lake stabilization project was estimated by determining the difference between the status quo income associated with option A and the estimated income assuming option D was adopted. (These options are described in Table 2. Status quo income was estimated to be $76,632. As can be seen in Table 29 the farm simulation closely approximated the actual total acreages of cornland, oatland, and hayland as well as production of grain forages, and milk. With a 90 percent subsidy rate for the option D manure storage facility net pre-tax earnings were estimated to be $77,890 (See Table 30) providing an income increase of $1,258.

Table 28--Annual Recreation Benefits at White Clay Lake Based on 7,477 Visits

Year a/	Change in Consumer Surplus	Discounted at 7-1/8 %	Discounted at 15 %
		---Dollars---	
1977	0	0	0
1978	0	0	0
1979	0	0	0
1980*	2,805	2,130	1,604
1981	2,805	1,988	1,395
1982	2,805	1,856	1,213
1983	2,805	3,077	1,870
1984*	4,973	2,867	1,626
1985	4,973	2,677	1,414
1986	4,973	2,499	1,229
1987	4,973	3,155	1,446
1988*	6,726	2,945	1,257
1989	6,726	2,749	1,093
1990	6,926	2,566	951
1991	6,726	2,918	1,007
1992*	8,194	2,724	876
1993	8,194	2,543	761
1994	8,194	2,314	662
1995	8,194	2,557	664
1996*	9,455	2,387	578
1997	9,455	2,228	502
1998	9,455	2,080	437
1999	9,455	2,168	424
2000*	10,559	2,024	369
2001	10,559	1,890	321
2002	10,559	1,764	279
2003	10,559	1,000	265
2004*	11,540	1,680	231
2005	11,540	1,568	200
2006	11,540	1,464	174
2007	11,540	1,471	163
2008*	12,424	1,373	147
2009	12,424	1,287	123
2010	12,424	1,197	107
2011	12,424	1,189	99
2012*	13,229	1,110	86
2013	13,229	1,036	75
2014	13,229	968	65
2015	13,229	953	60
2016	13,961	890	52
2017	13,961	831	45
2018	13,961	775	39
2019	13,961	759	36
2020*	14,633	710	34
2021	14,633	664	31
2022	14,663	620	28
2023	14,633	579	23
2024	14,633	540	21
2025	14,633	504	18
2026	14,633	470	16
Total discounted change in consumer surplus		$80,593	$24,091

a/Years in which water quality changes occur are denoted by an asterisk.

Table 29 --Comparison of Simulated Dairy Farm Operation with Representative Farm Operation, White Clay Region, Wisconsin, 1977

Item	Actual	Simulated
Pre-Tax Earnings	$73,943	$76,632
Milk Production		
Per Cow	140 CWT	140 CWT
Total Sales	$111,000	$108,354
Herd Size		
Dairy Cows	80	80
Replacement	90	90
Crop Average (Yield, Acre)		
Cornland	160 Acres	163 Acres
Grain	93 Acres (75 bushels)[a/]	67 Acres (83 bushels)[a/]
Silage	67 Acres (16 tons)	96 Acres (16 tons)
Oatland	35 Acres (60 bushels)	30 Acres (74 bushels)
Hayland	105 Acres (2.36 tons)	110 Acres (2.15 tons)
Purchases		
Fertilizer	$1,400	$3,173
Food Supplements	$2,000	$6,650

a/Figures in parentheses are per acre amounts.

Source: Information for the representative farm are from personal interviews.

Table 30 --Technology Choice for Wisconsin Dairy Farm with Various Cost-Share Rates

Subsidy	Option Chosen	Net Pre-Tax Earnings	Total Subsidy	Fertilizer Expenditure
		Subsidy on Storage Capacity Only		
0	A	$76,632	0	$3,173
41	C	76,637	$6,903	592
50	D	76,859	8,744	590
90	D	77,890	15,739	590
		Subsidy on Storage Capacity and Equipment		
32	C	76,640	6,979	592
40	D	76,895	8,988	590
90	D	78,554	20,239	590

To determine the total farm impacts in the watershed it was necessary to extrapolate the results from the representative farms to the other farms participating in the project. It was assumed that these impacts would be proportionate to herd size (Table 31). Total discounted farm impacts for these farms are $119,713 and $58,657 for the 7-1/8th and 15 percent discount rates, respectively.

Table 31 --Project Benefits to Farmers in White Clay Lake Watershed

Farm	Animal units a/	Estimated Annual Benefits
1	60	$ 408
2	60	408
3	50	340
4	145	986
5	55	374
6	50	340
7	100	680
8	40	272
9	65	447
10	120	816
11	60	408
12	185	1,258
13	115	782
14	190	1,292

a/Animal units are expressed in thousands of pounds, consequently, it may not necessarily coincide with actual number of livestock

Project Efficiency

As was the case in the Mirror and Shadow Lakes analyses project efficiency will be examined by comparing the present value of total discounted project benefits to discounted project costs. Benefits require the summing of the estimated recreational benefits and the farm benefits reflected by income changes. Total recreational benefits are $80,593 and $24,091 for 7-1/8 and 15 percent discount rates, respectively. The corresponding on-farm benefits are $119,913 and $58,675. Therefore, total project benefits are $200,306 and $82,766 when discounted at 7-1/8 and 15 percent, respectively. Total discounted project costs are $276,635 and $262,055 for the two discount rates and the relevant benefit-cost ratios are .72 and .32.

These results would suggest that this project is not justified, however, as is often the case, an examination of the circumstances can lend insights that can be helpful. In the case of White Clay Lake the magnitude of recreational benefits is not nearly so large as that at Mirror and Shadow Lakes. This is due to the smaller user population at this lake. This analysis did not consider a growth rate, but assumed a constant use pattern. This is perhaps not a realistic assumption, but it does avoid the problem of choosing a growth rate that is likely to draw possible criticism from project opponents who argue that benefits have been overestimated. A growth in recreational use of only 3 percent per annum would justify the project when evaluated at 7-1/8 percent discount rate.

In addition to allowance being made for increases in the user population consideration should also be given to the value placed on existence and option values which were not estimated.

It does appear, however, that the magnitude of the values placed on these considerations would have to be quite large to justify the project when discounted at a 15 percent rate.

Cost Sharing

Efforts to encourage voluntary participation in controlling nonpoint source pollution rely heavily on cost-sharing programs. From a policy standpoint the most interesting issue to examine was the determination of the break-even cost-share (subsidy) rates. The break-even subsidy rate can be identified as that rate which leaves the income of the farm unchanged after project adoption. At this rate, an income maximizing farmer is indifferent to the choices of implementing and not implementing the pollution reducing process.

As indicated above, there are two reasons this break-even subsidy rate is less than one-hundred percent of the cost of implementing less-polluting manure handling techniques, i.e., these techniques result in more nutrients being incorporated into the soil, thereby improving soil quality and decreasing purchases of commercial fertilizer, and these management systems require fewer labor and machinery hours to handle a given quantity of manure than do other systems such as daily surface spreading. Such benefits should help offset the capital costs incurred in adopting manure storage systems. 13/ The extent of these benefits was demonstrated in the preceding analysis on farm income.

13/Another benefit of the less-polluting handling techniques was identified in interviews with farmers. Since outdoor work in the winter is frequently uncomfortable, as well as being somewhat harder on equipment, the pollution-reducing technique which does not require winter spreading has an advantage over the daily handling method, which requires spreading during the winter season. Unfortunately, the model was not equipped to assess the magnitude of this benefit because labor was treated as a homogenous resource throughout the year.

To examine the cost-share issue we will consider two cost-sharing programs. The first program is similar to the one administered at the White Clay Lake. Funds can only be used to finance the construction of manure storage facilities; participants must finance the purchase of all manure collection and spreading equipment. Participants are required to choose between management options B, C, and D, (Table 2) and per farm grants are limited to $26,000. This figure equals the amount of funds received by some individuals under the White Clay Lake program. Each of the management options (B, C, or D) results in identical levels of nutrient runoff. Therefore, in terms of pollution, federal and state governments should be indifferent to an individual farmer's choice of these options.

The second program also allows a choice between B, C, and D. However, this program would allow subsidy funds to be applied to all categories of capital costs, including equipment, which are incurred in implementing one of the three options. The limit on per farm payments under this program is also $26,000.

Both programs directly affect farm operations and the level of net pre-tax income by changing the investment costs associated with options B, C, and D. Hereafter, the proportion of investment expenses absorbed by participants in the cost-sharing programs is referred to as the cost share.

The participant's cost-share rate for system i under program j, r_i^j (where i = B, C, D and j = 1,2), can be calculated for any given subsidy rate, s, and the set of rules governing the cost-sharing program. Let K_i represent the per-ton cost of capacity (including the cost of either a piston pump or a stacker) needed for option i, and let E_i be the per-ton cost of other equipment (in the case of the three options, a spreader) needed to implement that option.

In the first subsidy program,

$$r_i^1 = \frac{(1-s)K_i + E_i}{K_i + E_i} > 1-s, \ (i=B,C,D) \tag{26}$$

and in the second program

$$r_i^2 = \frac{(1-s)\ K_i + E_i)}{K_i + E_i} > 1-s \tag{27}$$

Clearly, for any positive value of s, r_i^1 exceeds r_i^2 for all i.

Under each program, there is a maximum percentage of the total investment costs for an option which a revenue maximizing farmer will be willing to absorb and still use that option. Corresponding to this maximum percentage, which is referred to as the "break-even cost share" ($\hat{r}_i^j$), is the minimum, or break-even subsidy rate" ($\hat{s}_i^j$), i.e.:

$$\hat{r}_i^j = 1 - \hat{s}_i^j \tag{28}$$

Because the government will only help pay for storage capacity costs, (K_i) in the first program, but will help pay for all capital costs (K_i+E_i) in the second program, the break-even cost-share rate for option i is less in program 2 than it is in program 1, i.e., $\hat{r}_i^1 > \hat{r}_i^2$.

The government's proportion of cost, s, was varied under each program, and the level of farm income and choice of manure handling system was observed. The results of these simulations are reported in Table 30.

Under rules of the first cost-sharing program, where only the storage facility is subsidized, the break-even subsidy rate is approximately forty-one percent. Since storage facility costs are a higher proportion of total investment costs for option C than for the other options, r_C exceeds both r_B and r_D. Therefore, the higher rate of government subsidization of the

former option's capital costs make it a relatively attractive investment option. Option C is the only handling process used in the model when the break-even rate is offered, and total subsidy payments are approximately $6,900, well below the per-farm grant limit. As subsidy rates increase, the differences between the options' capital costs decrease. For rates of fifty percent and above, the lower labor requirements of option D make it more attractive than option C from the vantage point of the representative farm.

In the second program, where all equipment can be subsidized, the break-even subsidy rate is thirty-two percent. Again, system C is choosen by the model at the minimum subsidy level, and total payments to the farm are a little less than $7,000. As the subsidy rate increases above forty percent, it is profitable to switch to option D.

There is no combination of cost shares and program rules for which option B is used in the model. Its comparatively high capital cost outweighs benefits the farm would gain from the slightly higher delivery of nitrogen from a ton of manure. This benefit is small because the farm is barely able to use all the nitrogen delivered by options C or D. The shadow price of a pound of nitrogen in the break-even runs is five cents. Shadow prices for phosphorus and potassium are higher, indicating that amounts of these fertilizer elements available are fully utilized on the farm. However, a switch to option B would not increase the production of phosphorus and potassium.

Finally, when a subsidy rate in the range of thirty-two to fifty percent is offered to cost-sharing program participants, rules of the program affect the choice between manure handling systems. Under the institutional structure of the present program, option A is chosen if a subsidy rate between thirty-two and forty percent is offered. System C is used if an

identical rate is offered under the second set of rules. Similarly, if a subsidy rate of forty to fifty percent is offered under the first rule set, option C is selected; but in the same range of subsidy rates for the second institutional structure, handling method D is the most profitable choice. These results indicate that farmers would be able to pay a rate significantly higher than the cost-share arrangements used at White Clay Lake.

These results have significant policy implications. In the case of manure storage facilities, it appears that the farmer may actually be benefiting from the employment of cost-shared nonpoint source pollution control measures. If so, re-evaluation of the existing cost-share structure is in order. We are not claiming that our findings should be adopted as they stand. However, the direction of our findings does have the support of other research efforts, and with the potential benefits as great as they appear to be, the issue should justify further investigation, particularly with public funds as scarce as they are.

Change is difficult to obtain, particularly when it requires higher cost shares from the participator. To ease acceptance of this change an educational program should capitalize on the farmers sensitivity to the probability of private gain from certain cost-sharing programs. Consequently, the educational program must inform farmers of the possible gains from adopting anti-pollution technology - not only the direct gains, such as nutrient retention associated with manure storage facilities, but also the indirect ones, such as more free time, healthier cows and a means to delay manure spreading during inclement weather. In addition, a comprehensive educational program must point out the other financial incentives available, such as tax deductions and low-interest loans. Perhaps a combination of

incentives might be appropriate. The various incentives are not mutually exclusive; thus, a combination of them might form an attractive package. For example, a low-interest loan might be used to supply the capital for the farmer's cost share.

This discussion has dealt only with cost sharing and manure storage facilities. However, nonpoint source pollution control measures include many other structural and non-structural approaches, and all are cost shared. To provide an efficient cost-share program, it will be necessary to conduct similar research efforts for each of these.

CONCLUSIONS

In the process of developing *ex ante* evaluation techniques and performing an economic analysis of a lake rehabilitation and lake stabilization project, implications for tax assessment and cost-sharing were also revealed.

Each of the projects were evaluated with a property value impact model, a recreation demand model, and a LP farm simulation model. Such techniques provide the opportunity not only to determine if a given project is economically efficient, but also to make the comparison between projects competing for agency funds.

At Mirror/Shadow Lakes the property value model is applicable for estimating all local benefits associated with the improvement in water quality. Its application requires information on property values, distances of properties from the water resource, and water quality experts' projections of water quality changes.

To account for the estimation of benefits not capitalized in property values, it was necessary to employ an alternative estimation technique.

On the assumption that most of the benefits of the rehabilitation project at Mirror and Shadow Lakes are primarily recreational, a travel cost recreation demand model with a water quality explanatory variable was used to estimate the benefits accruing to nonlocal users.

The impacts estimated with these models revealed a favorable ratio of benefits to costs of 2.73 and 1.86 when discounted at 7-1/8 and 15 percent, respectively.

These ratios suggest that the project was an efficient use of resources, although not necessarily an optimal one. However, in the process of estimating the property value impacts it became clear that the distribution of benefits was not commensurate with the mill rate used to generate the funds to pay the local cost-share of the project. This discrepancy in the distribution of the benefits and costs is attributable to the difference in proximity of the affected properties to the water, and in the case of Mirror Lake riparian property owners exclusively to the resource. Consequently, the increase in the well-being of the property owners closer to the resource comes at the expense of those further away.

If the goal of local decisionmakers is to design a more equitable tax instrument, based on the welfare criteria of "benefits received", then it is necessary to provide as much conformity as possible between the incidence of project costs and benefits. This can be readily and inexpensively accomplished using the property value impact model to predict what the benefits to property owners will be in a district and then allocating the project costs in proportion to those benefits.

To analyze the impacts at White Clay Lake it was necessary to employ both the recreation model as was used in the previous analysis and an LP model that would simulate the impact on farm revenue of adopting a manure storage facility used to deal with the nonpoint source pollution problem

endangering the nearby lake. In this analysis it did not appear that with ceteris parabus conditions the project is economically efficient. This was evidenced by the benefit-cost ratios of .72 and .32 evaluated at 7-1/8 and 15 percent, respectively. No attempt was made to estimate the option value and existence value associated with this resource. These values aside, it is estimated that a three percent per annum increase in recreational use would produce a favorable benefit-cost ratio. In sum, the decision on whether the stabilization project is economically justified is not clear cut as was the lake rehabilitation project at Waupaca.

Of particular interest when employing the LP model to determine farm impacts of adopting manure storage facilities was the realization that government subsidies do not need to be as high as they presently are. Reduced subsidy rates need not detract from the preadoption income of the farmer. For the case at hand a break-even rate was estimated at 32 percent, well below the 90 percent offered in the project. When one considers that this project is one of many to be undertaken nationwide, it becomes apparent that a revised cost-sharing arrangement could possibly have a large impact on a water program relying on limited public funds, either by subsidizing the same number of projects for less, or more for the same amount of funds.

However, it is recognized that change is difficult to obtain, particularly when it requires higher cost shares by the participants. To ease acceptance of this change an educational program should capitalize on the farmers' sensitivity to the probability of private gain from cost-sharing programs. Consequently, the educational program must inform participators of the possible gains of accepting anti-pollution technology. In addition, a comprehensive educational program must point out the other financial incentives available such as tax deductions and low interest loans. Such efforts will lead to more successful nonpoint source pollution control programs.

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